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The Development of Rice Production and Research in the Federation of Nigeria

J. E. Y. Hardcastle

Federal Department of Agricultural Research, Nigeria

Recent attempts to give a comprehensive picture of the agricultural resources of Nigeria have revealed that rice is now the sixth major domestic food crop of the country (Anon., 1951; Prest and Stewart, 1953) (*Figure 1*). The area cropped with rice is estimated at just under half a million acres. The annual production of paddy from this area, cropped once a year, is estimated at nearly a quarter of a million tons. The entire annual production is consumed within the country and is valued at £10 000 000 at prices ruling in Nigeria today. Imports of rice into Nigeria are negligible.

Approximately one fifth of the total production still consists of 'red' rice derived from the indigenous West African cultivated species *Oryza glaberrima*. The bulk of the crop, however, consists of white rice derived from varieties of *Oryza sativa* introduced by the Department of Agriculture less than 40 years ago.

No complete account of this achievement has ever been published. Brief mention is made of successive introductions of varieties of *Oryza sativa*, and details of the gradual expansion of production are given, in several of the *Annual Reports* of the Nigerian Department of Agriculture from 1920 onwards, and general accounts of rice production in the West African territories are given in the textbooks of Faulkner and Mackie (1933) and Irvine (1934). However, the only published accounts of rice production in Nigeria are those of Glanville, Dowson and Buckley appearing in the *Proceedings* of the third West African Agricultural Conference (Anon., 1938). These deal only with the experimental clearing and cultivation of mangrove swamp in the Niger Delta following upon the survey carried out by R. R. Glanville, of the Sierra Leone Department of Agriculture, in 1933.

The intention of the writer, therefore, is to give a more comprehensive picture of the development of the Nigerian rice industry to the present day and to review the prospects for a further expansion of production.

Development of Rice Production

The origins of rice cultivation in Nigeria

Rice cultivation in Nigeria originated with the introduction during the sixteenth century of the indigenous West African species, *O. glaberrima* Steud., to the inundated flood plains of what is now Northern Nigeria whither, according to Portères (1950), it had spread from an original centre of variation in the Central Niger Delta. Since almost all the numerous varieties of this 'red' rice now grown in Nigeria possess the

floating habit, in contrast to the upland habit which the species evolved elsewhere in Africa, it would appear that the Northern Nigerian flood plains provided a unique ecological niche and possibly a secondary centre of diversity. Adaptation to a wide range of flood depths and soil types has taken place and numerous varieties can be recognized.

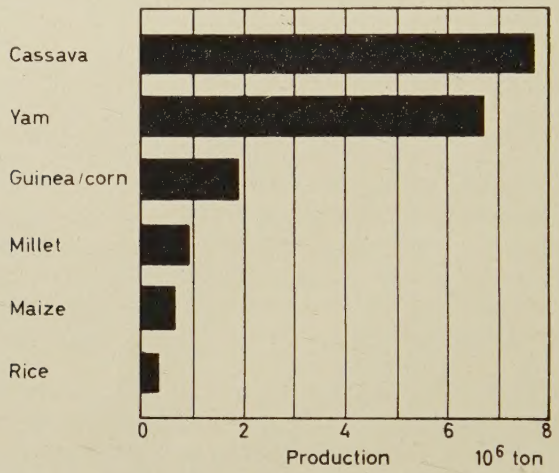

Figure 1. Production of major Nigerian domestic food crops, in their most processed form, about 1950–51 (data derived from PREST *and* STEWART, 1953)

The earliest cultivation of 'white' rice, *Oryza sativa* L., in Nigeria apparently commenced less than 80 years ago when upland varieties were introduced to the high forest zone of Western Nigeria. This contrasts markedly with the situation elsewhere in West Africa where *Oryza sativa* was introduced by Portugese navigators in the fifteenth and sixteenth centuries (PORTÈRES, 1950; JORDAN, 1954). No evidence is yet available to show by whom the introductions to Nigeria were made but it is believed that the white rice replaced upland varieties of red rice formerly in cultivation. The earliest recorded introductions of white rice are those made by the Department of Agriculture after 1919. Shallow swamp varieties from British Guiana and Ceylon were successfully established in the shallow flooding valleys (*fadama*) of the smaller tributaries of the Kaduna, Niger and Benue Rivers where they rapidly replaced the swamp varieties of red rice then extensively cultivated. Today, swamp cultivation of *Oryza glaberrima* is mostly confined to the far north of Nigeria where it is particularly well adapted to the rapid fluctuations in flood depths that occur.

Zones of rice cultivation

Four typical zones may be recognized in which rice can be grown in Nigeria. In their present order of importance these are: naturally inundated land, land provided with supplementary irrigation, land not subject to inundation but receiving sufficient rainfall, and tidal fresh-water mangrove swamp.

Within the category of naturally inundated land come the periodically flooded river valleys, or *fadamas*, of Northern Nigeria, and also the relatively small but numerous, rain-fed inland swamps so successfully developed in the Eastern Region.

Throughout Northern Nigeria rainfall is inadequate for rice cultivation (Rae, 1944). In India the normal requirement for swamp rice is estimated at 60 to 80 in., well distributed, throughout the growing season. The mean annual rainfall in Northern Nigeria varies between 50 to 60 in. in the south and 20 to 30 in. in the far north. In either case rather less than two thirds of the total falls between July and September and rainfall in October is markedly reduced and irregular. For this reason rice cultivation, originating with the introduction of *Oryza glaberrima*, has been confined to the *fadamas* where the period of inundation extends beyond the end of the rains and into the critical period when the rice is heading. It is significant that the few upland varieties of red rice grown in the north are of short duration.

The *fadama* floods, however, are characterized by a rapid rise and vary from year to year in time of onset, duration and depth. Deep flooding precludes the use of much valuable land and the varieties of white rice so far introduced do not possess the tolerance shown by the indigenous red rice to this environment. Nevertheless, despite the risk of flood damage, the pre-existence of rice cultivation in the *fadamas* has led inevitably to the greater part of the Nigerian white rice crop being grown on the margins of the inundated areas. Some 300 000 acres are now in cultivation and the potential area is vast. Rae (1944) estimated that over 200 000 potential acres existed in Bida Division of Niger Province alone and a further 200 000 acres in the Rima Valley in Sokoto Province.

Fadama soils vary in fertility since the texture varies from pure sand to heavy silty clay and the distribution pattern is often complex.

The inland valley swamps of the Eastern Region present a complete contrast to the northern *fadamas*. With the average annual rainfall varying between 60 to 80 in. inland and over 160 in. on the coast the primary development problem is one of improving the natural drainage to prevent deep flooding. The swamps are individually quite small but altogether constitute a very large acreage. At present it is estimated that more than 40 000 acres are in cultivation in Ogoja Province and 10 000 acres in Onitsha Province. Soils vary from heavy clays to lateritic soils.

Several irrigation schemes have been initiated in the northern region and the acreage of swamp rice receiving supplementary water supplies is slowly increasing and probably amounts to 10 000 acres. Such schemes are still experimental and usually take the form of a diversion weir on a perennial stream and a distributary channel network over the area commanded. No large water storage reservoirs have been included in the schemes so far constructed but several include flood protection embankments. The principal schemes are in Niger and Sokoto Provinces.

Upland rice grown on non-inundated land under high rainfall is at present of most importance in the Western Region and Southern Cameroons where it is grown on land cleared of high rain forest. It has been estimated that over 20 000 acres are cultivated with upland rice in the Western Region.

The cultivation of rice in tidal fresh-water mangrove swamp is, as yet, in the experimental stage in Nigeria. Areas so far cleared have proved very fertile and able to repay the high initial cost of clearing.

Cultural methods

These vary widely according to the climate and flood conditions and the experience of the farming population. In the *fadamas* of the far north where red rice is still cultivated, the season often commences with a deep hoe cultivation in April. A further hoeing in May removes the germinated volunteer rice of the previous season. The rice seed is then broadcast at rates up to 100 lb/acre with the early rains, some four to five weeks before the expected rise of the flood. Since the floods do not recede until November or December it is not uncommon for the deep-water varieties to be harvested from canoes. The rapid development of a competitive population of perennial wild rice, *Oryza barthii* Chev., on cultivated land necessitates a three year fallow being taken every three to five years. During the rains, systematic weeding under water (*yin dono* in Hausa) of the wild rice is sometimes practised until the *fadama* grasses again become dominant. The land is then fit for cultivation once more.

In Niger, Benue and Ilorin Provinces, where the bulk of the white rice is grown on the margins of the inundated *fadamas*, cultivation does not commence until June. The land is then hoed into narrow ridges which are seeded at rates of 40 to 50 lb/acre. Frequent weeding is necessary. Some attempt is usually made to conserve rain water by individual construction of irregular retaining bunds.

Transplanting is only practised where supplementary irrigation schemes assure an extended water supply. In such cases the sowing of nurseries commences in June and transplanting into partially levelled and bunded fields in July, though transplanting may take place as late as September if the water supply is guaranteed throughout the dry season.

In both the small rain-fed inland swamps and the mangrove clearance schemes of the Eastern Region transplanting is almost universal. Rice cultivation was introduced to the Eastern Region as late as 1944 and the extension staff of the Department of Agriculture have placed much emphasis on the careful timing of planting and accurate spacing of seedlings.

During the first few years of a mangrove swamp clearance scheme the existence of a two-foot thick mat of mangrove root fibres, known locally as *chikoko*, necessitates cultivation with a cutlass to permit the seedlings to be transplanted. Later this fibrous mat is incorporated with the typical mangrove swamp mud underlying it and thereafter hoe cultivation is practised. Usually a dry season growth of sedges has to be removed before cultivation but during the rains the diurnal flooding almost eliminates weed growth.

In the high forest zone of the Western Region no further cultivation is carried out after clearing and burning, and direct seeding at spaced intervals takes place in May or June. Interplanting with maize is sometimes practised. The upland rice farms normally develop very high weed populations and are seldom cropped more than once.

In the Northern and Eastern Regions the whole plant is harvested, the straw being cut at six to nine inches from the ground and made into a sheaf. The sheaves are then stacked in a circle, heads inward for drying, prior to threshing. Methods of threshing are more varied.

In the far north the sheaves are spread on an earth floor and flailed. Elsewhere in the north the sheaves are beaten out in a hole in the ground. In the east the slatted threshing table is sometimes used. The panicles only are harvested in the Western Region and, after drying, are flailed on an earthen floor. Winnowing everywhere is carried out by the women who deftly toss the grain in round, flat, woven trays allowing the breeze to carry away the chaff.

Varieties

Numerous varieties of red rice are known to the farmers of Northern Nigeria and varying degrees of adaptation to the range of flood depths and soil types are undoubtedly recognized. These varieties are further distinguished by striking differences in spikelet morphology and life period, though grain shape and size are fairly uniform and all possess the characteristic red caryopsis (*Figure 2*). Most varieties possess a vitreous grain but the red caryopsis is difficult to mill off in entirety and therefore milled red rice is much less acceptable to the expanding consumer market familiar with white rice. The present distribution of red rice cultivation is shown in *Figure 3*.

In the post-1945 period several deep-water white rice varieties were introduced from Sierra Leone but proved unsuitable for the deep flooding *fadamas* though they have served to familiarize the Nigerian consumer with a variety of grain types.

Cultivation of white upland rice in the Western Region is restricted to one varietal complex (*Figure 3*) generally known as Agbede, though numerous synonyms exist. Both subtypes of the complex are characterized by bold grain and a glutinous endosperm (*Figure 4*). Their origin is unknown though it is believed they were introduced to the coast less than 80 years ago.

The shallow swamp varieties of *O. sativa*, which later were to constitute the bulk of the production of the Northern and Eastern Regions, were first introduced to the Northern Region after 1919. Several strains of Demerara Creole, a long-grain rice from British Guiana, were introduced by the Agricultural Department in 1920–21. Of these, strain Guiana 79, now known as BG 79, rapidly gained popularity and fresh stocks have been re-introduced on several occasions. The variety GEB 24, from Madras, was introduced via Sierra Leone in 1934. This variety retains favour in some parts of the north by virtue of its palatability and is used in ceremonial gifts between chiefs. BG 79, however, due to its short (five month) growing season, superior yield and good milling quality has gradually superseded all the other varieties (*Figure 4*). Today it constitutes the bulk of the crop from both Northern and Eastern Regions (*Figure 3*). Its yield varies with environment and method of cultivation from 750 to 4 000 lb/acre. The present demand from the shallow swamp areas is for a higher yielding variety maturing earlier than BG 79 and therefore less susceptible to late season drought.

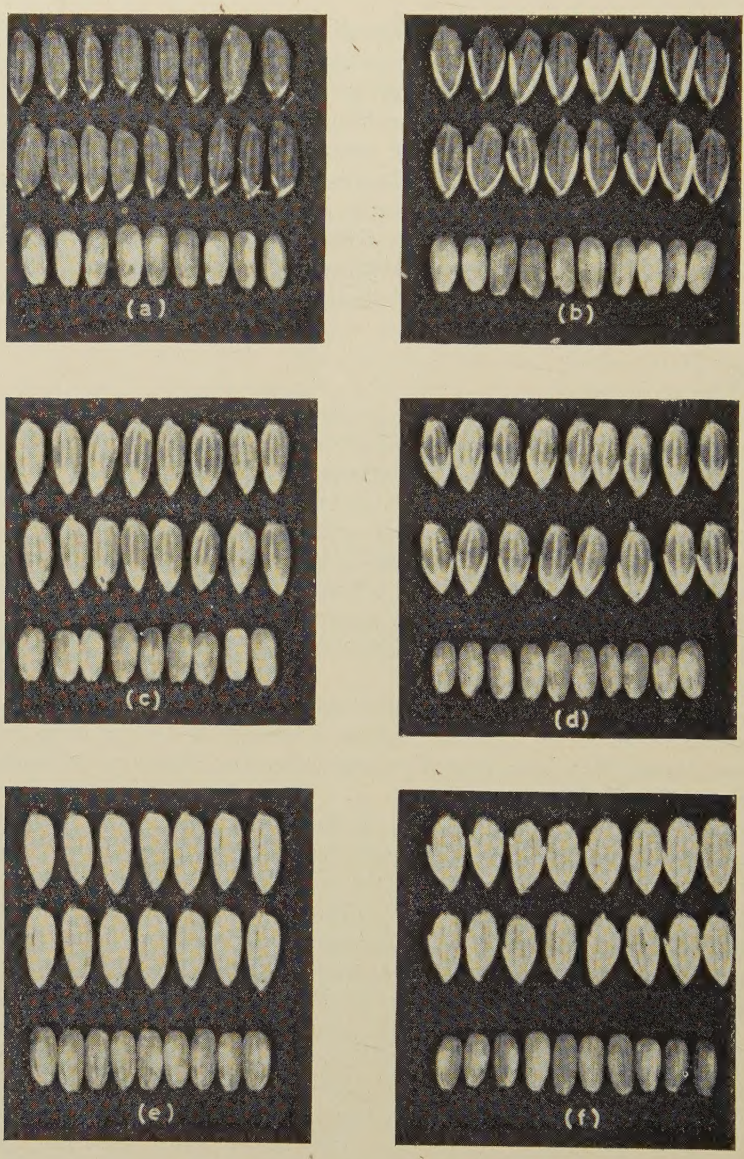

Figure 2. Morphological variation in spikelets of some Nigerian varieties of Oryza glaberrima *Steud. Magnification* × *1·25.. Spikelets* (a) *and* (b) *glabrous, black;* (c) *and* (d) *glabrous, brown with yellow ribs and keels;* (e) *glabrous, yellow;* (f) *pubescent, yellow. Types* (a) *to* (e) *are classified as* subsp. vera *Chev.; type* (f) *is* subsp. confusa *Chev. Types* (a), (c) *and* (e) *are classified, on length of sterile glumes, as* var. breviglumis *Cam. et Vig., and types* (b), (d), (f) *as* var. longiglumis *Cam. et Vig. The caryopsis is a dark red colour in all cases*

Processing

Parboiling of paddy is almost universal in Nigeria and is encouraged for dietary reasons. The vessels used range from small clay pots to old petrol drums. In the north it is traditionally the work of the women,

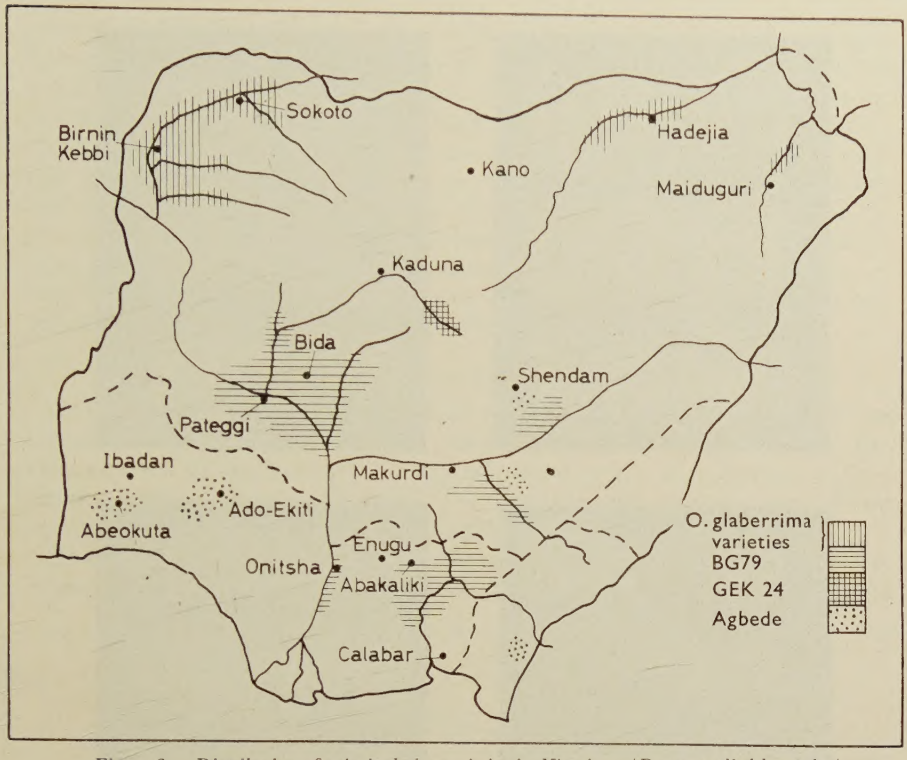

Figure 3. Distribution of principal rice varieties in Nigeria. (Data supplied by author)

carried out primarily to enable the husk to be separated more easily from the grain with the wooden pestle and mortar (DALZIEL, 1936). The few rice mills so far established in the north usually purchase and polish surplus rice already husked in this manner. The polished rice is then disposed of to traders from the south. Parboiling is an important middleman enterprise in the Eastern Region serving both the farmers and the very large milling industry which has developed at Abakaliki in Ogoja Province. From this town rice is exported to all the principal markets in the country. In the Western Region parboiling is carried out by the farmers while milling is performed by the numerous private mills.

Storage

The normal coincidence of the marked dry season with the harvesting of the rice crop in the north ensures adequate drying before storage. Paddy retained for consumption or seed is stored in the large, thatch-roofed clay bins, supported off the ground, which are a common sight in the walled family compounds. Both paddy and milled rice, when stored in sacks awaiting disposal to a trader, are seldom kept long enough to enable high rates of insect infestation to build up.

Consumption

There are several forms of consumption of rice in Nigeria. The preparation of *Jollof* rice probably antedates the introduction of the present upland

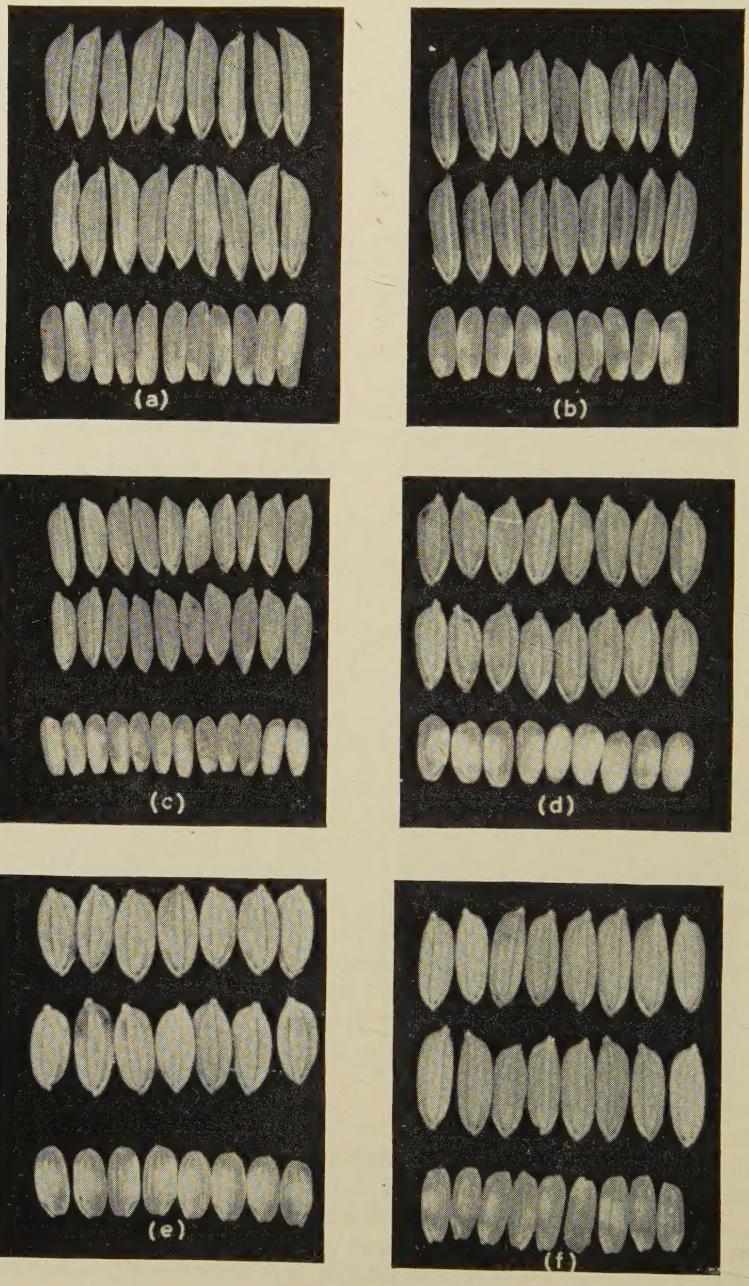

Figure 4. The principal Nigerian varieties of Oryza sativa, *classified according to grain shape and size (Ref.* Beale, R. A. 1927). *Magnification* × 1·5. (a) *variety Guiana Creole, Emata type;* (b) *variety BG 79,* Letywesin *type;* (c) *variety GEB 24,* Letywesin *type;* (d) *variety Ngasein 57,* Ngasein *type;* (e) *and* (f) Medon *and* Letywesin *types in the Agbede varietal complex*

rices of the Western Region. The recipe is believed to have been brought from Sierra Leone and is associated with Lagos and the transfer of Lagosians in government service to the principal ports and cities of the east and west in the early part of this century. *Jollof* rice is prepared by cooking condiments, oils and meats, according to taste, with the rice. A similar preparation is known in the Hausa North as *dafa duka*. Elsewhere in the north rice has been integrated in the local diet in the traditional way, that is by the preparation of a paste or gruel, known as *tuwon shinkafa*, eaten with a separate sauce or soup. The consumption of plain boiled white rice is found primarily amongst the Ibo peoples of the Eastern Region, though condiments, oils and meats may be added after the cooking process.

PRESENT DISTRIBUTION OF PRODUCTION

The estimates quoted here are based on those of the Agricultural Sample Census (ANON., 1951) and upon subsequent information given by the Departments of Agriculture. The map showing the distribution of production within Nigeria (*Figure 5*) is a diagrammatic representation of the census data and does not purport to show the area occupied by rice.

The Northern Region is the largest producer of rice in Nigeria today. Though the cultivation of red rice is not now so extensive, the annual

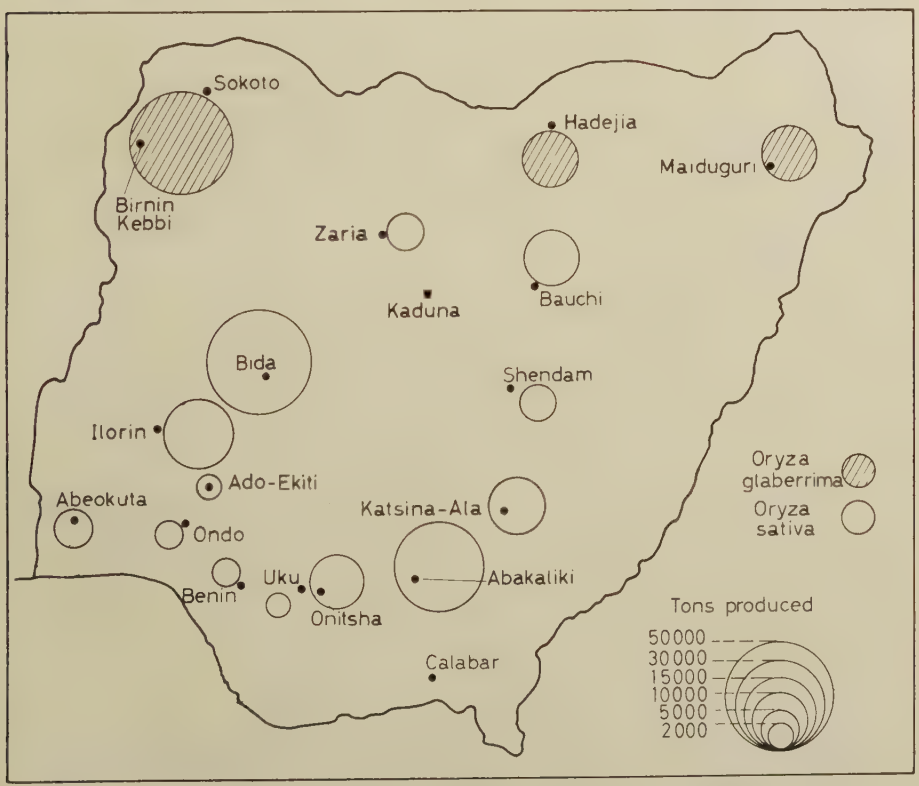

Figure 5. Distribution of rice production in Nigeria. (*Data derived from* Sample Census of Agriculture. ANON., 1951)

production is estimated to exceed 90 000 tons. Sokoto Province alone produces 70 000 tons annually. Red rice constitutes about 40 per cent of the Regional production and 30 per cent of the entire production of Nigeria.

Following the introduction of white rice to Northern Nigeria, subsequent efforts made to popularize the new crop were intensified during the Government's ' Grow More Food ' campaign during 1939–45 with the result that today the Northern Region contributes an estimated annual 96 000 tons or 65 per cent of Nigeria's white rice production and nearly 76 per cent of the total annual crop.

The Eastern Region contributes some 30 per cent of Nigeria's white rice production and 20 per cent of the annual total. This is a notable achievement since rice cultivation was only introduced by the Department of Agriculture as late as 1944. Under the continued guidance of the Department, production is now estimated at 40 000 tons per annum from the rain-fed inland swamps of Ogoja and Onitsha Provinces.

The cultivation of rice in both the Western Region and Southern Cameroons is restricted to white upland varieties. The Western Region and Southern Cameroons together contribute some 10 000 tons annually. This amounts to 8 per cent of the white rice production but only 4 per cent of the total production.

THE NEED TO INCREASE PRODUCTION

The need to secure a substantial increase in all food crop production was particularly stressed in the report of the recent International Bank Mission to Nigeria (IBRD, 1955). The Federation of Nigeria is the most populous country in Africa. Its population, recently estimated at 32 millions, is increasing by 2·1 per cent per annum. An immediate increase in the production of all the domestic food crops is necessary if the present level of consumption is to be maintained.

There is an urgent need, however, even at the present time, to improve the dietary balance. It has been calculated by Nicol (1956) that the average energy requirement of the Nigerian adult is 2 600 calories per day. The calorie intake of the guinea corn- and millet-consuming peoples of the north is satisfactory, but that of the yam- and cassava-consuming peoples of the south is seldom adequate. Animal protein is generally in short supply and the alternative vegetable protein, while adequately supplied by the northern cereal diet, is poorly represented in the starchy root diet of the south. Compared with yam and cassava, parboiled milled rice is rich in protein and the further expansion of rice production in the Eastern and Western Regions could do much to improve the dietary balance in this respect.

Prospects of increasing the acreage

Of all the domestic food crops of Nigeria rice appears to offer the most favourable opportunities for a substantial short-term, nation-wide expansion in production, primarily by bringing into cultivation the tidal fresh-water mangrove swamps of the Eastern Region and the vast areas of unused *fadama* in the Northern Region.

Various recommendations have been made by visiting rice and agricultural experts concerning those areas which are most suitable for development, but all have agreed that the potential acreage is enormous. 25 years ago Glanville (Anon., 1938) estimated that 300 000 to 600 000 acres could be utilized in the mangrove swamps of the Niger Delta. Subsequent writers were also in agreement (e.g. Anon., 1938). Later, however, Rae (1944), examining the prospects for development by irrigation in Northern Nigeria, made proposals for commanding 200 000 acres of the Kaduna–Gbako plains in Niger Province and 200 000 acres of the Rima valley in Sokoto Province. The recent International Bank Mission (IBRD, 1955) endorsed the development of up to 100 000 acres by irrigation in Niger Province whilst also recommending anew Glanville's proposals for the immediate development of 100 000 acres in the Eastern Region mangrove swamps. Expenditure to the extent of £1 500 000 on irrigation schemes and mangrove swamp clearance was recommended in order to achieve a short term annual increase in production of 150 000 to 200 000 tons.

Few of the large scale recommendations concerning the Northern Region have been implemented. One reason for this has been that major civil engineering works would be necessary to provide flood control, water storage and irrigation facilities to extend the short growing season. However, the climatic and hydrological information necessary to start even small scale ' pilot ' irrigation schemes is lacking. The early failure of the Kwarre irrigation scheme, now reconstructed, and the recent temporary abandonment of the Lake Chad scheme forcibly demonstrate the importance of such information. Data are now being slowly acquired by the Northern Region Irrigation Division from small scale schemes of 2 000 to 3 000 acres. In the interim, work is proceeding on numerous small, low cost, irrigation schemes designed to supplement limited rainfall in shallow flooding *fadamas*.

Another factor which has not hitherto been adequately recognized is the markedly superior adaptation of the indigenous red rices to the rapidly flooding conditions in the *fadamas* of the far north. The large existing acreage of red rice in these areas has given rise to unduly optimistic estimates of the potential increase in white rice production which requires quite different water conditions. Present strains of white rice have proved unsuitable for these areas.

As a potential means of increasing the acreage of rice production, partial mechanization of cultivation has met with moderate technical success, notably at Sokoto (10 000 acres) and Shemankar (5 000 acres) in the Northern Region. This has enabled farmers to bring into cultivation areas too difficult for hoe tillage. However, the economics of mechanization in relation to Nigerian agricultural systems have yet to be worked out.

A more promising method of increasing the rice acreage in Nigeria is today believed to lie in the clearing and development of the mangrove swamps of the Eastern Region. The present cost of development, still at the pilot stage, is approximately £35 per acre, but yields exceeding one ton may be obtained regularly from this fertile soil. The Bank Mission foresaw an eventual expansion to one million acres. Development is at present centred on Brass Division of Rivers Province, where it is hoped to attract

the Ijaw fishing peoples to rice cultivation, which promises them a higher standard of living.

Increasing the yield per acre

While the possibilities of increasing the acreage of rice production commend themselves as a short term solution of the problem it is generally realized that the long term development of the industry must be based upon increasing the yield per acre.

Though the estimates of the 1950 sample census were only an approximation it is generally agreed that yields throughout Nigeria are low. In the white rice producing areas of the Northern Region yield estimates varied from 1 600 lb/acre in Ilorin Province to 945 lb/acre in Benue Province. The data for the Western Region and the Southern Cameroons ranged from 500 to 750 lb/acre and reflected the lower yields associated with upland rice production. In the Eastern Region yield estimates from the inland swamps of Ogoja and Onitsha Provinces ranged from 1 120 to 1 344 lb/acre.

It has been suggested by Grist (1953) that rice yields are affected by latitude. The normal average yield of milled rice produced between latitudes 0° and 10° is half that of temperate countries in latitudes 30° to 40°. This suggests that climatic conditions may impose limiting factors on potential rice yields.

The 1950 sample census indicated a national average yield of 1 306 lb/acre, which is equivalent to 10·1 quintals per hectare of milled rice. This quantity appears to be within the average yield of rice when the crop is grown between latitudes 0° and 10° and is apparently greater than that attained in any other country in Africa excluding Egypt. However, yields of milled rice obtained from Nigerian Government farms have varied from 21·7 to 23·5 quintals per hectare. These farms have been sited on soils ranging from sandy river alluvium to heavy mangrove clays. It is therefore evident that an improvement in the national yield average could be achieved simply by raising the general standard of cultural practices and improving the crop material.

The need for research

The problems of enhancing the yield per acre of rice in Nigeria are, however, numerous and include many of a fundamental nature requiring organized research. Thus, little is known of the optimum irrigation requirements of the *fadama* soils or of conservation of water in the areas of low rainfall. Nothing is known of the water requirements of the rice plant in the various phases of its development under the wide range of environments found in Nigeria. While the limited number of manurial trials on rice have already shown that economic responses can sometimes be obtained by the application of small dressings of artificials, the few soil surveys of rice areas so far made have often revealed a complex distribution of a wide range of soil series. An organized repetition of both simple and complex manurial trials over all the rice producing areas will be necessary before any reliable conclusions can be drawn.

It was long ago realized that the establishment of a specific commodity research station was necessary if organized research into these problems

was to be undertaken. Recommendations for the establishment of a rice research station to serve all the West African territories were first put forward before 1939. (Anon., 1938; Sampson, Crowther and Doherty, 1943). Due to the war, however, the establishment of the West African Rice Research Station, at Rokupr in Sierra Leone, did not take place until 1945.

Establishment of the Nigerian Rice Research Station

By 1945, however, Nigeria's rice production had increased by 25 per cent over the 1939 level (Prest and Stewart, 1953) and, as a result, the need to establish rice research stations within Nigeria became apparent. Due to the shortage of trained personnel proposals were shelved until 1947, when a plan for three rice research stations was approved but not put into effect. It was not until 1953 that it became possible to establish the Federal Rice Research Station at Badeggi in the Niger Province of the Northern Region where it is centrally placed with regard to all the existing rice producing areas (*Figure 5*).

CURRENT RESEARCH

Due to the continuing shortage of staff and the inevitable development phase from which the station is emerging, current investigations have remained experimental and mainly devoted to the improvement of crop material. In this, as in all other aspects of the research programme, close liaison is being maintained with the West African Rice Research Station in Sierra Leone.

Yield improvement

The plant breeding programme is designed to produce higher yielding varieties suitably adapted to the agronomic and economic requirements of the four zones of cultivation.

High priority is being given to the riverine areas subject to rapidly rising deep floods where at present only floating varieties of *O. glaberrima* survive. These conditions do not appear to be paralleled in the ancient centres of cultivation of *O. sativa*. The long adapted variety Mbagboli from Sierra Leone has appeared most promising in recent trials but further introductions are now being observed. While growth studies of both *O. glaberrima* and *O. sativa* varieties in shallow-water conditions reveal no variation in the growth rate, observations are being continued under natural deep-water conditions until the projected deep-water study tank is completed.

An extensive collection of indigenous Nigerian varieties has been made for the purpose of devising an agrobotanical classification, and on the basis of this a hybridization programme with selected varieties of both species was commenced in 1957. The object is to combine the colour and quality of the *O. sativa* grain with the superior adaptation to the environment of the *O. glaberrima* varieties. Using Rhind's hybridization technique (Jordan, 1957) 500 crosses gave 47 mature seed. All proved inviable though Ramiah and Rao (1953) have stated that the species are easily hybridized. The project was to be repeated on a larger scale in 1958.

Equal priority has been given to those areas protected by flood control schemes or subject to shallow natural inundation, with or without supplementary irrigation. These are the areas currently cropped with the white rice BG 79, and as a result of this and the large internal trade in white rice between Regions there is a strong preference now for this type of medium long grain in mills and markets all over Nigeria. This is being taken into account when introducing new varieties.

Some 35 shallow swamp varieties are currently entered in five yield trials. Commenced in 1956 and replicated at all the Regional rice growing centres, each trial includes varieties of similar duration. Combined results of 1956 and 1957 from all areas show that, of the five-month varieties, the British Guiana selections D 114 and D 52/37 and the Indonesian selection MAS 2401 all significantly outyield BG 79. Of the later varieties D 99 ($5\frac{1}{2}$ months) from British Guiana, TOMA 112 (6 months) from Sierra Leone, and PTB —16 (7 months) from India have all outyielded the established varieties. Trials of three- and four-month varieties, more suitable for the short Northern growing season, were laid down in 1958.

The present shallow swamp trials are being replicated in the mangrove swamps but it is foreseen that scarcity of labour and the long growing season will require the introduction of non-photosensitive varieties of varying duration in order to stagger the harvest. Due to the high level of fertility, greater resistance to lodging and fungal disease, notably *Helminthosporium oryzae*, is required of varieties for this area, at present cropped with the ubiquitous BG 79. Upland rice, until recently confined to the Western Region, is now being encouraged by the Northern Region Department of Agriculture in response to the demand for an earlier rice crop. At present field trials are being conducted in the Western Region. Most of the varieties under trial have vitreous grain, unlike the established Agbede complex, and may improve both yield and milling quality.

Improvement of quality

Beale's classification of grain shape and size (Beale, 1927) has been adopted as a basis for canalizing introductions for those zones where the introduction of *O. sativa* presents no difficulties.

The first objective is to ensure that within any one locality, all new varieties issued will possess the same grain shape and size. This should effectively reduce the percentage of broken grain resulting when mixed paddy is milled. This is a common occurrence in the Northern Region, where successive introductions of white rice have resulted in the mixed cultivation of varieties of widely differing shape and size (*Figure 4*).

Parboiling is universal in Nigeria and continued adoption of the ' Emata ' or ' Letywesin ' groups of long grain, similar to BG 79, involves no loss in milling quality or conversion ratio (see *Figure 4*). The bolder ' Ngasein ' types are unpalatable to most Nigerian consumers, though the extent of the demand for the glutinous upland rices of the Western Region remains to be assessed. The development of preference amongst the farmers, traders, millers and consumers is in process of survey.

Preliminary investigations of the comparative milling quality of *O. glaberrima* and *O. sativa* have revealed surprisingly little difference if the

hulling process is separated from the whitening process. Milling in Nigeria is universally carried out with Engleberg-type hullers which remove husk and bran in one process. Further laboratory investigations into milling quality of both red and white rices are being carried out under a complete range of processes. Investigation of cooking quality of the new introductions is also in progress. Cooking quality has to be related to the preferences of the widest consumer market which may differ from that of the local producers.

Seed multiplication

Expenditure on varietal improvement is wasted unless the improvement is actually reflected in the nation's annual production returns. As Ramiah (1953) affirms, the absence of an efficient large scale seed multiplication and distribution system in India negated 30 years of varietal improvement. It is therefore encouraging to note that in Nigeria the foundations of a four-stage rice seed multiplication programme have recently been established in each Region. The combined programme is designed to produce 750 to 1 000 tons of pure seed every year, sufficient to replace one fifth of Nigeria's present annual seed requirement.

Soil fertility

Soil fertility studies have included laboratory and field investigations of the nutrient status of the alluvial soils of the northern *fadama*, based upon a preliminary soil survey in 1953 of part of the Kaduna river *fadama*. Very few rice areas in Nigeria have as yet been soil-surveyed but there is reason to believe that the present work will have application to many of the northern *fadamas*. Fertilizer trials in progress since 1955 on a wide range of soils have demonstrated yield responses to economic dressings of inorganic fertilizers, particularly ammonium sulphate. Diminished responses to economic dressings of ammonium sulphate in the presence of similar dressings of superphosphate may indicate a level of nitrogen deficiency beyond the possibility of economic remedy at the present time.

Cultural investigations

Preliminary investigations have demonstrated that, in irrigated alluvial soils, the optimum spacing for transplanted rice is 9 in. × 9 in. while the stand population is immaterial. Studies of yield response to seed dressing have been inconclusive, possibly due to the low incidence of fungal rice disease at Badeggi. The economic use of weedkillers is receiving attention, while a related investigation into manual and mechanized rice cultivations is planned in association with the Northern Region Ministry of Agriculture. Further experimental and fundamental studies on manurial and cultural problems are being commenced as staff and the provision of facilities and equipment permit.

SUMMARY

Rice production in Nigeria originated with the introduction of floating varieties of *O. glaberrima* Steud. during the sixteenth century. Varieties of *O. sativa* L. were not introduced until the late nineteenth century and

present production is still restricted to a few varieties. The zones and methods of cultivation are described.

The total annual production has been estimated at 250 000 tons of which approximately 160 000 tons consists of 'white' rice and 90 000 tons of 'red' rice, the latter all grown in the Northern Region. The Northern Region also produces 110 000 tons of white rice, the Eastern Region 40 000 tons, and the Western Region 10 000 tons.

The need to increase food production is urgent and an increase in production of rice would also improve the dietary balance of the Western and Eastern Regions.

The prospects of increasing the acreage of rice cultivation are potentially good but development in the north has been hindered by the lack of basic hydrological data. Development of the fresh-water mangrove swamps in the Eastern Region, though expensive, may prove to be a swifter method at the present time.

The prospects of increasing yield per acre are also potentially good but there is need for research into a wide range of problems. This need has been met, in part, by the establishment of a Nigerian Rice Research Station working in liaison with the West African Rice Research Station, Sierra Leone.

Since 1953 the research programme of the Nigerian Rice Research Station has been mainly devoted to the improvement of the crop material in relation to the ecological environment. Quality is receiving equal attention. A national seed multiplication scheme has been founded.

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REFERENCES

Anon. (1938). *Third West African Agricultural Conference Papers*, Vol. I, pp 491–519. Federal Government Printer, Lagos

Anon. (1951). *Report on the Sample Census of Agriculture*, 1950–51. Federal Government Printer, Lagos

Beale, R. A. (1927). 'A scheme of classification of the varieties of rice found in Burma.' *Bull. Agric. Res. Inst. Pusa* No. 167

Dalziel, J. M. (1936). *The Useful Plants of West Tropical Africa*, p 533. Crown Agents for Overseas Governments and Administrations, London

Faulkner, O. T. and Mackie, J. R. (1933). *West African Agriculture*, pp 142–145. Cambridge University Press, London

Grist, D. H. (1953). *Rice*, pp 266 and 270. Longmans, Green: London

International Bank for Reconstruction and Development (IBRD). (1955). *The Economic Development of Nigeria*, pp 19–20, 150–151, 157–158, 214–220. Williams and Wilkins, Baltimore

Irvine, F. R. (1934). *West African Agriculture*, pp 89–98. Oxford University Press, London

Jordan, H. D. (1954). 'The development of rice research in Sierra Leone.' *Trop. Agriculture, Trin.* **31**, 27

Jordan, H. D. (1957). 'Hybridization of rice.' *Trop. Agriculture, Trin.* **34**, 133–136

Nicol, B. M. (1956). *Feeding Nigeria*, pp 8–12. Federal Government Printer, Lagos

Portères, R. (1950). 'Vieilles agricultures de l'Afrique Intertropicale.' *Agron. trop., Nogent*, Nos. 9–10, pp 490–494

PREST, A. R. and STEWART, I. G. (1953). *The National Income of Nigeria 1950–51*, pp 26–27. [*Colonial Research Study No. 11*]. Her Majesty's Stationery Office, London

RAE, C. J. (1944). *Report on Agricultural Development by means of Irrigation and Drainage in Nigeria.* Colonial Office, London

RAMIAH, K. and RAO, M. B. V. N. (1953). *Rice Breeding and Genetics,* pp 9 and 97. Indian Council of Agricultural Research

SAMPSON, H. C., CROWTHER, E. M. and DOHERTY, A. C. *Report of the West African Commission 1938–39*, p 57. Waterlow, London

Some Responses of the Rice Plant to Growth-regulating Substances

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Effects of growth-regulating substances on different crop plants have been observed by numerous workers. However, the study of the effects of these substances on the growth and yield of the rice plant has received little attention. With sand culture experiments, Gopalachari (1952) reported an increase in grain yield of rice due to α-naphthalene acetic acid when applied along with the nutrient solution. After-effects of pre-soaking of grains of an early rice variety with growth regulators, adopting pot techniques, have been studied by Misra and Sahu (1957a). They observed a significant increase in tiller and leaf formation in plants obtained from grains treated with 250 and 500 p.p.m. of indole acetic acid and 2,3,5-triiodobenzoic acid solutions. Differences in grain yield were not significant.

In Malwa tract of Madhya Pradesh (India) rice is grown as a single crop, sown with rains by the end of June or at the beginning of July and harvested by the middle of November. It is exclusively grown as a monsoon crop. The average rainfall is about 35 in. Bullock-sowing is the common practice as only 10 to 15 per cent of the crop is under irrigation. A preliminary investigation was therefore conducted to study the effects of several growth-regulating substances on the growth and yield of rice plants in this tract.

MATERIALS AND METHODS

In the first year, i.e. 1955–56 season, two rice varieties, Basmati (*Oryza sativa*) and Barwani-22 (*Oryza sativa*) were grown in pots three quarters filled with soil and one quarter, farmyard manure. Seeds were sown on 30 June and the plants were treated with the auxins when 32 days old. Aqueous solutions of the following growth regulators (without a wetting agent) were sprayed at the rate of 10 ml per plant.

The treatments were: control, α-naphthalene acetic acid (NAA), indolylacetic acid (IAA), phenoxyacetic acid (PAA), and 2,3,5-triiodobenzoic acid (TIBA). These substances will be referred to hereafter by their abbreviations. For each growth regulator there were three concentrations, namely 20, 30 and 40 p.p.m. Thus, including the control, there were 13 treatments. Five pots per treatment were kept, each pot containing two plants of Basmati and Barwani-22.

In 1956–57, a small-scale field trial with Basmati and Barwani-22 was laid out. The plot size was 15 ft × 2 ft 4 in. There were three blocks. The crop was sown on 28 June and treated on 30 July. The treatments were: control, NAA, PAA, TIBA, β-3-indolylpropionic acid (IPA) and β-naphthoxyacetic acid (NAPH). Concentration of each auxin was 10, 15 and 20 p.p.m., except NAA which was applied at 15 p.p.m. only. There were 14 treatments. Aqueous solutions of each hormone were applied at the rate of 80 gallons per acre. No wetting agent was used.

At maturity, observations on tillers, ears, weight of 100 grains, yield, etc., were recorded.

RESULTS

In pots as well as field trials Basmati did not respond to any of the growth regulators. Results obtained with Basmati are therefore not included. Results of Barwani-22 alone are summarized in *Tables 1* and *2*.

Table 1. Effect of growth regulators on plant characters (pot experiment)

No.	Treatment Substance	p.p.m.	Tillers per plant	Ears per plant	Wt of 100 seeds g	Yield of paddy per plant g
1.	*Control*		6·86	6·03	2·34	5·7
2.	*NAA*	20	4·73	3·86	2·38	2·2
3.	*NAA*	30	4·39	4·13	2·49	3·2
4.	*NAA*	40	4·66	4·06	2·61	3·4
5.	*IAA*	20	6·76	5·96	2·59	3·5
6.	*IAA*	30	6·19	4·66	2·61	3·9
7.	*IAA*	40	5·53	4·79	2·58	2·8
8.	*PAA*	20	5·76	5·36	2·63	4·3
9.	*PAA*	30	4·19	4·00	2·58	2·6
10.	*PAA*	40	7·59	6·39	2·69	3·9
11.	*TIBA*	20	6·23	4·73	2·61	3·9
12.	*TIBA*	30	10·20*	8·50*	2·56	6·7
13.	*TIBA*	40	6·30	4·60	2·59	4·1
	S.E.		0·92	0·71	0·099	0·85
	Sig. diff. at 1%		2·60	2·00	0·31	(*at* 5%) 2·4

*Significant at 1 per cent level.

It will be seen that none of the growth regulators produced any beneficial effect on the rice plant except the 30 p.p.m. concentration of TIBA. Auxins depressed the production of tillers, number of ears and grain yield per plant. Plants treated with 30 p.p.m. of TIBA showed a significant increase in the number of tillers and ears per plant. The grain yield per plant increased by 1 g but was not found to be significant over the control. There was a

Table 2. Effect on ear-emergence and paddy yield under different treatments (1956–57)

No.	Treatment Substance	p.p.m.	No. of days for ear emergence after sowing (Mean of 12 plants)	Paddy yield lb/acre	Straw yield lb/acre	Wt of 100 seeds g
1.	*Control*		54·0	1048·5	1112·7	3·1
2.	*PAA*	10	51·0	831·6	879·3	3·1
3.	*PAA*	15	52·0	848·1	879·3	3·0
4.	*PAA*	20	53·0	1048·5	1034·9	3·1
5.	*IPA*	10	52·6	990·8	1034·9	3·1
6.	*IPA*	15	51·6	688·9	723·6	3·0
7.	*IPA*	20	53·3	834·4	902·6	3·1
8.	*NAPH*	10	55·0	867·3	980·4	3·0
9.	*NAPH*	15	52·0	708·1	747·0	3·1
10.	*NAPH*	20	52·6	1062·2	1136·1	3·1
11.	*TIBA*	10	55·6	1004·6	1011·6	3·0
12.	*TIBA*	15	50·3	1059·4	1058·2	3·1
13.	*TIBA*	20	52·0	1257·1	1322·8	3·1
14.	*NAA*	15	54·0	628·5	723·6	3·1
	S.E.		—	94·1	94·2	0·049
	Sig. diff. at 1%		—	274·5	273·9	—

slight increase in the weight of 100 seeds over the control under all treatments. In plants treated with 40 p.p.m. of PAA, even though the number of ears per plant was the same as for the untreated plants, there was a reduction in grain setting and consequently low yield.

In the field trials, there was no significant effect on earliness due to hormone treatment. Plants treated with 15 p.p.m. of TIBA flowered four days earlier than the control plants. The number of days taken for ear-emergence varied from 50·3 to 55·6 under different treatments.

Paddy yields remained more or less unaffected in plants treated with 20 p.p.m. of PAA and NAPH, and decreased under low concentrations of these auxins. Similarly all the concentrations of IPA failed to produce any response in this rice variety. Paddy yield increased by 200 lb over the control yield with a 20 p.p.m. concentration of TIBA. The medium dose of 15 p.p.m. was level with the control values but the lower concentration showed a decline. The increase in yield effected by TIBA though considerable did not reach the level of significance. Similar trends were noticed in the yield of straw per acre under these treatments. Weight of 100 seeds under all treatments remained unaffected.

DISCUSSION

The plot size adopted in the field trial may appear rather inadequate for maximum efficiency. However, there are considerable difficulties in adopting a larger plot size on account of the general practice in this tract of sowing paddy by a pair of bullocks. As transplanting is not resorted to because of lack of irrigation facilities, considerable gaps remain in the field rendering it unsuitable for treatment and selection for a bigger plot.

Out of several growth regulators tried, only TIBA produced some beneficial effects on growth and yield of the rice plant in pots as well as field experiments. Negative results obtained with Basmati indicated differences in varietal behaviour as regards treatment with TIBA. Similar differential behaviour in apple varieties to NAA applications was reported by Gardner *et al.* (1939), and in cotton varieties by Bhatt (1958).

In plants treated with TIBA, the number of ears and tillers per plant were significantly higher than those in the untreated plants. Different workers on rice in India (Ghose *et al.*, 1956) have found a fairly high amount of correlation between yield and number of ears per plant. Also, Mahalanobis (1934) and Ramiah (1954), summarizing the results obtained with a number of rice varieties, have found a moderate correlation between mean yield and number of tillers per plant. Thus, responses due to TIBA suggest further investigations into the auxin treatment of rice by suitable modifications in auxin concentration, time and mode of application.

Results obtained by different workers are rather conflicting as regards the effect of auxins on the flowering behaviour of the rice plant. With high concentration and excessive auxin treatment Sircar and Kundu (1955) observed very early ear emergence in the variety Rupsail, while no such conspicuous earliness was noted by Misra and Sahu (1957b) using other rice varieties. In the present investigation also earliness could not be induced by auxin treatment.

SUMMARY

Experiments with several plant growth regulators on two rice varieties indicated differences in varietal behaviour. Treatments with 2,3,5-triiodobenzoic acid alone promoted growth and yield of the rice plant to a certain extent. Other treatments produced deleterious effects on plant development. There was no effect on earliness.

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REFERENCES

Bhatt, J. G. (1958). 'Differential behaviour in yield of American and Desi cotton varieties in Malwa tract to treatment with several plant hormones.' *Cot. Grow. Rev.* **12,** 80–82

Gardner, F. W., Marth, P. C. and Batjer, L. F. (1939). 'Spraying with plant growth substances to prevent apple fruit dropping.' *Science,* **90,** 208–9

Ghose, R. L. M., Ghatge, M. B. and Subrahmanyan, V. (1956). *Rice in India.* Indian Council of Agricultural Research, New Delhi

Gopalachari, N. C. (1952). 'Phytohormones and nitrogen deficiency in paddy.' *Madras agric. J.* **39,** 437–443

Mahalanobis, P. C. (1934). 'A preliminary note on intervarietal correlation in the rice plant in Bengal.' *Plant Breed. Abstr.* **4,** Abstract No. 545

Misra, G. and Sahu, G. (1957a). 'After-effects of treatment of grains of an early rice variety with plant growth substances.' *Curr. Sci.* **26,** 258

Misra, G. and Sahu, G. (1957b). 'Control of flowering in rice by plant growth substances.' *Nature, Lond.* **180,** 816

Ramiah, K. (1954). 'Factors affecting rice production.' *F.A.O. Agricultural Development Paper No. 45*

Sircar, S. M. and Kundu, M. (1955). 'Effect of auxins on the flowering behaviour of rice.' *Nature, Lond.* **176,** 840–41

Deficiency Symptoms of the Major Elements in the Banana

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There appears to be little published information on the mineral nutrition of the banana. With the rapid expansion of this crop in the West Indies, more especially in the Eastern Caribbean, the need arises for a better understanding of its physiological needs in respect to the major elements. Not only would descriptions of the effects of mineral deficiencies assist in their correction in the field by the use of fertilizers but, as the banana is so often used as a temporary shade plant in the establishment of cacao, signs of unbalanced nutrition in the banana could give assistance in dealing with similar problems in cacao.

The symptoms of deficiencies of nitrogen, phosphorus, potassium, calcium and magnesium have therefore been produced by growth in sand culture and the technique employed is given below.

EXPERIMENTAL METHODS

Containers

The containers used were 12 in. clay pots locally made to a special pattern. They had a single side hole at the bottom into which was inserted a rubber bung carrying a bent glass tube. When upright this tube retained the culture solution in the pot to the level of the top of the sand. By twisting the tube downwards the solution could be run into a Winchester bottle. The pots were painted internally with three coats of inert bitumastic paint.

Sand

Two grades of extremely coarse silica sand were used. In one series the particle size averaged 0·5 to 2 mm; in the other, practically a gravel, particle size averaged 3 to 4 mm. Previous experience with cacao had emphasized the importance of adequate drainage and aeration. For cacao Long Ashton sand had proved far too fine and resulted in poor growth and induced iron deficiency. There was no appreciable difference in growth of plants in the two grades of sand under the watering régime employed. No signs of water stress developed in the plants for the first four to six months of growth even with the coarser particle size. The sand was acid washed, rinsed in demineralized water and placed in the pots over a layer of glass wool.

Water

The nutrient solutions were made up with demineralized water from a commercial ion-exchange installation. Conductivity determinations proved it superior to ordinary glass-distilled water and its easier production was a great advantage with the large quantities concerned in this work.

Culture solutions

The complete solution was based on HEWITT's (1952) Long Ashton formula with slight modifications. Previous work with cacao (MASKELL, EVANS and MURRAY, 1953) had indicated that the higher levels of nitrogen and potassium led to better growth and these were therefore adopted for the banana.

The stock solutions were:

KNO_3	.. .. ..	101 g/l.
$Ca(NO_3)_2.4H_2O$	.. ..	188·8 g/l.
$MgSO_4.7H_2O$	.. ..	73·8 g/l.
$NaH_2PO_4.2H_2O$	.. ..	41·6 g/l.

When diluted 100 times in making up the working nutrient solutions, these gave concentrations as milligramme equivalents per litre of: NO_3^-, 15; PO_4^{---}, 4; SO_4^{--}, 3; K^+, 5; Ca^{++}, 8; Mg^{++}, 3.

In previous work with cacao some difficulty with iron nutrition was experienced until it was supplied as the chelate with ethylene diamine tetra acetic acid. For the present work iron was supplied at 5 p.p.m. as the chelate with diethylene triamine penta acetic acid. The other micro-nutrients followed the Long Ashton formula. Apart from using A.R. reagents, no special purification of the various salts was undertaken.

In the deficiency cultures, potassium, calcium and magnesium were substituted by the equivalent amount of sodium, and nitrate and phosphate by sulphate.

At the start, the solutions were used at half strength and changed to full strength after the first month. Two litres of culture solutions were used per plant and the solutions were changed every two weeks.

Plant material

Although it would have been possible and perhaps easier to have worked with seedling material of non-edible *Musa* species, it was considered preferable to work with a commercial variety and the Dwarf Cavendish was selected. This involved using young suckers and with the appreciable amount of food reserve stored in the corm a longer period of growth would be needed before deficiency symptoms might be expected. As, however, it was proposed to take samples for leaf analysis more material would be available from greater growth and larger leaves. For micro-nutrient studies, however, it would probably be essential to use seedlings.

The suckers were dug from a field at River Estate when the first leaves were just appearing and were planted temporarily in buckets in unpurified sand and watered with tap water. At the end of a month they were dug up, thoroughly washed, wet weight determined and planted in the pots. For the first week they were watered only with demineralized water before starting with the various culture solutions.

Watering schedule

The routine adopted was to raise the bent glass tube in the pot and pour in from a Winchester 2 l. of solution. This quantity filled the pot to the top of the sand. After half an hour the tube was turned down and the

solution allowed to drain back into the Winchester. This procedure was followed morning and afternoon; even at the height of the dry season no sign of water stress developed in the plants for the first six months. To replace the water lost by transpiration, the Winchesters were always made up to the 2 l. mark with demineralized water before pouring the solution into the pot.

General

The treatments were set up in duplicate, giving in all 12 pots (five deficiencies and control) and these were grown in a glass house transmitting some 60 to 70 per cent of full sunlight. Although situated in an area where leaf spot is prevalent no trouble was experienced and no control measure was necessary.

DEFICIENCY SYMPTOMS

Nitrogen deficiency

Absence of a supply of nitrogen shows up more quickly than that of any of the other major nutrients. The symptoms involve a stunting of growth as a result of a reduction both in the rate of leaf production and in the size of leaf developed. The new leaves are progressively smaller and paler in colour and there is also a gradual loss in colour of the older leaves as nitrogen is translocated from them to the young leaves. All leaves become a pale yellow green (*Figure 1* and *Plate 1*). With continuing shortage of nitrogen

Figure 1. Nitrogen deficiency. Top, healthy leaf; bottom, left to right, leaves 1 to 5. Note reduced size of deficient leaves becoming more marked with youngest leaves. General paleness as compared with control and narrow yellow green margin to leaves 3 and 4, leaf 5 is yellowing due to premature senescence. Little marginal necrosis except in oldest leaf

Plate 1
Nitrogen deficiency

Plate 2
Phosphorus deficiency

Plate 3
Potassium deficiency

Plate 4
Calcium deficiency

Plate 5
Magnesium deficiency

there is a more marked loss in colour along the margin of the leaf and this eventually becomes necrotic. Necrosis, however, is not always associated with nitrogen deficiency except in the oldest leaves. The leaf petioles are short, thin and compressed. The roots are markedly thin but are as numerous and lengthy as in the controls. There is a reduction in suckering, neither of the nitrogen-deficient plants producing any suckers.

Phosphorus deficiency

Phosphorus deficiency leads to a reduction in growth mainly through a slower rate of leaf production, the actual size of leaf being little affected. Young leaves appear a healthy green, the first symptoms occurring on leaves about five or six back from the spear. On these a slight marginal chlorosis develops along the distal edge and extending about two thirds of the way to the base. In the pale area, purplish brown flecks develop. These are angular and internal to the margin and they gradually spread and coalesce (*Figure 2*, leaf 7). Chlorosis spreads inwards to the mid-rib (*Figure 2*, leaf 8 and *Plate 2*), sometimes leaving islands of healthy green tissue. This rapid progression of necrosis towards the mid-rib distinguishes phosphorus from the cation deficiencies. The necrosis of tissues proceeds very rapidly, the leaf dries up and the petiole breaks at the pseudo-stem.

Figure 2. Phosphorus deficiency. Increasing severity of symptoms, left to right, leaves 4, 5 slight marginal necrosis, 7 marked marginal necrosis in angular patches, 8 tissue breakdown and yellowing reaching to mid-rib succeeded by brownish black necrosis, 9 most advanced state ending with leaf senescence

Potassium deficiency

Deficiency in potassium again results in a marked reduction in growth and this becomes very pronounced before any leaf symptoms appear. The interval between the production of new leaves becomes longer and the leaves are progressively smaller. Leaf symptoms when they develop are seen on the older leaves, the young leaves remaining green.

The old leaves lose their colour from the margin inwards and a marginal necrosis may develop (*Figure 3*, middle leaf). Usually, however, the chlorosis progresses very rapidly so that in a day or two the whole leaf becomes yellow (*Plate 3*). It then dries up and the petiole breaks. Necrosis tends to spread from the edges whenever the leaf becomes torn.

Figure 3. Potassium deficiency. Left to right, healthy leaf; chlorosis and yellowing with marginal necrosis; final stage, leaf senescent, yellow with necrosis at all edges

The symptoms of potassium deficiency are very similar to those of the normal senescence of old leaves in healthy plants and would appear to operate through an upset in the water relations of the leaf. A potassium-deficient plant tends to have fewer leaves since the older leaves die off prematurely.

Calcium deficiency

Symptoms of calcium deficiency are rather slower in appearing than with other deficiencies and are first manifest on the fourth or fifth oldest leaves as a gradual loss of colour in a narrow band along the margin (*Figure 4*, leaf 6; *Plate 4*). The inner edge of the chlorotic area remains parallel to the leaf margin without developing inwards as with the marginal necroses of other deficiencies. Within this band a type of pin-head flecking develops,

Figure 4. Calcium deficiency. Left to right, leaves 6, 7, 8, 9. Normal green colour of leaf with broad yellow green marginal band. This develops a marginal necrosis which does not progress towards mid-rib until it has developed almost entirely along the margin

Figure 5. Magnesium deficiency. Leaves becoming progressively smaller and opening before complete emergence

with small brownish black isolated spots uniformly distributed in the yellowing zone. Gradually necrosis sets in but it tends to remain marginal until the leaf turns yellow and becomes senescent.

(a)

(b)

(c)

Figure 6. Magnesium deficiency. Range of symptoms: (a) *Slight marginal necrosis and internal necrotic spotting. Note slight interveinal chlorosis.* (b) *No marginal necrosis, tissue browning internally and near mid-rib.* (c) *Close-up showing brown necrotic patches surrounded by yellow senescent areas*

A calcium-deficient plant was the only one of the series to produce a new sucker. Roots tend to be short, stubby and much branched and are very susceptible to eelworm and fungal attack.

Magnesium deficiency

One plant showed a very pronounced compression of the young leaves, these starting to unroll before they had completely emerged from the sheathing leaf base. This symptom is shown in *Figure 5*. As the other plant did not show this marked compression it may not be a typical diagnostic symptom.

The leaf symptoms shown in *Figure 6* are, however, very distinctive. Starting on the fourth or fifth leaf there is a gradual loss in colour and brown spots appear both on the margin and internally (*Plate 5*). Marginal necrosis is, however, slight in comparison with the internal necrotic areas which become surrounded by yellow senescent tissue. An interveinal chlorosis (*Figure 6*) may occur but it is thought that this symptom, so typical of iron chlorosis in other plants, may have been an associated induced iron deficiency. This is borne out by the fact that increasing the iron supply in the nutrient solution led to a reduction in this symptom.

CONCLUSION

Although the visual symptoms here described and illustrated should prove of assistance in diagnosing malnutrition in the field, it must be realized that the symptoms are a result of very acute deficiency and that minor degrees of deficiency, sufficient to reduce growth and yield, may not be so easily recognized—more especially as in the field the incidence of leaf spot is usually an added complication. Confirmation is required either from field trials in which the suspected deficient nutrient is supplied as a fertilizer or by leaf analysis. For the latter a very comprehensive sampling of the plants was undertaken and a subsequent paper will describe the effects of the various deficiencies on the leaf content of nitrogen, phosphorus, potassium, calcium and magnesium.

It is desirable also that the micro-nutrient deficiency symptoms be produced and described to complete the picture. A more refined technique will be necessary for this and it will probably be necessary to use seedling material to reduce the effects of the considerable reservoir of nutrients in the corm.

SUMMARY

(*1*) Bananas have been grown in sand culture in the absence of each of the five major nutrients in turn.

(*2*) The technique employed is described and the deficiency symptoms produced are described and illustrated.

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REFERENCES

Hewitt, E. J. (1952). 'Sand and water culture methods used in the study of plant nutrition.' *Tech. Commun. No. 22.* Commonwealth Bureau of Horticulture and Plantation Crops

Maskell, E. J., Evans, H. and Murray, D. B. (1953). 'The symptoms of nutritional deficiencies in cacao produced in sand and water cultures.' *Report on Cacao Research 1945–51.* Imperial College of Tropical Agriculture, Trinidad

The Influence of Growth-promoting Substances on Pineapples

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The use of growth-promoting substances to control flowering in pineapples is far from being a new idea. In 1932 Rodriguez (cf. Malan, 1954) found that an atmosphere containing ethylene gas encouraged eary flowering in pineapples. Today, growth-promoting substances are being used in Hawaii and South Africa. Other countries (Harland, 1953) have also used growth-promoting substances to bring pineapples into flower at convenient times and by their use it has been possible to induce more uniform fruiting together with increased yields. In Australia (Cannon, 1955) one of the methods advocated in controlling 'Black Heart' disease is the use of hormones to accelerate fruiting and thus prevent cold season harvesting.

With the expansion of the pineapple industry in Kenya, which started in 1950, a number of field trials were laid down. The emphasis of these trials was on fertilizers and spacing, but in view of the growing importance which other pineapple-producing countries appeared to attach to the use of hormones, it was decided to start simple investigations to study the influence of growth-promoting substances on the fruiting of pineapples as well.

The six trials to be described in this paper were conducted between the years 1951 and 1956.

CLIMATE

The trials were carried out in the Ruiru and Thika districts of the Central Province. These districts cover the present centre of the pineapple-growing industry. The altitude is approximately 5400 ft and the average annual rainfall is about 36 in. The annual rainfall varies considerably, and during the five-year period of the trials it ranged from 27·99 to 50·04 in. The rainfall distribution follows the monsoon pattern with two seasons each year, the Long Rains occur between March and June, and the Short Rains between October and December.

Mean yearly temperatures range between 55° and 83°F. The temperature can fall to 42°F and rise to over 90°F.

EXPERIMENTAL

The object of the trials was to find out what influence growth-promoting substances would have on pineapple flowering, harvesting and fruit weight, and which of these substances would prove the most useful and in what concentrations. The substances tested were 1-naphthylacetic acid, β-indolylbutyric acid, 'Hortomone A', 'Planofix', 'Seradix A', 'Anapal', dichlorophenoxyacetic acid, 'Dicotox' (based on 2,4-D), and acetylene from calcium carbide.

The design of the experiments was of single plots to each treatment. Plot size varied from six plants per plot in the smallest trial to 380 plants in the largest trial.

Treatments were applied to plants by a Dronwal stirrup pump in the form of a mist spray. In one trial, Trial III, the treatments were applied by the cup method at the rate of 80 cm^3 poured into the heart of each plant. By the mist spray method, each plant was thoroughly wetted and the rate of application was approximately 40 cm^3 per plant. In all except Trial III, the treatments were applied at, or about, the time of natural flowering. The plants in Trial III were composed of 16 leaves and though immature were considered to be large enough to receive treatment. Application of the treatments was made in the morning between 10 a.m. and noon provided rain did not threaten.

Crop recording was carried out as the fruit became ripe, each fruit being weighed separately.

RESULTS

Trial I

Trial I was treated during April 1951, when the plants were eight months old. As this was the Long Rains season, the plants were well supplied with moisture before and after the treatments were made. The rainfall up to the time of treatment was 23·80 in. During the three months following treatment, a further 11·47 in. of rain was recorded.

The planting material was composed of suckers which normally produce ripe fruit in about 18 months from planting. Since the harvesting of the untreated plants, as shown in *Table 1*, coincided with the harvesting of the treated plants, the conclusion is that the treatments were applied at the time of natural flowering. No marked acceleration of the harvests could, therefore, be expected during the first month as a result of the treatments. Acceleration of the harvests was, however, becoming evident from some of the treatments during the second month. The three β-indolylbutyric acid treatments and two of the ' Hortomone A' treatments increased fruiting. The β-indolylbutyric acid treatment of 0·5 g to 500 cm^3 of water substantially increased fruiting and fruit weight.

' Hortomone A' at a concentration of 1·0 cm^3 to 500 cm^3 of water produced the most favourable response in accelerating the harvest. In the first three months, 61 per cent of the fruit from this treatment had been harvested while in the same period only 28 per cent of the untreated plants had been harvested. Fruiting and fruit weight were also increased. ' Dicotox ' in all concentrations suppressed fruiting.

Trial II

Treatments were applied to ten months old plants which originated from suckers. Application of the treatments was made during March 1952.

The plants were in flower when the treatments were applied. As the Long Rains normally begin in March, the plants were not well supplied with moisture at the time of treatment. Between January and the time of treatment, only 1·97 in. of rain had been recorded. Of this total, 1·50 in. fell during March, but no rain had fallen during the 18 days before the treatments were applied. During the three months following treatment, the plants were well supplied with moisture, 24·77 in. of rain being recorded during that period.

Table 1. (Plant crop)
(48 plants per plot. Suckers treated May 1951, 8 months after planting.)

Treatments in water	*'Hortomone A'*			*β-Indolylbutyric acid*			*'Dicotox'*			*Control*
Concentration	0·25 *cm³*: 500 *cm³*	0·5 *cm³*: 500 *cm³*	1·0 *cm³*: 500 *cm³*	0·25 *g*: 500 *cm³*	0·5 *g*: 500 *cm³*	1·0 *g*: 500 *cm³*	0·125 *cm³*: 500 *cm³*	0·25 *cm³*: 500 *cm³*	1·0 *cm³*: 500 *cm³*	
% Harvested at months after treatment 8	6·0	4·0	6·0	4·0	3·0	12·0	4·0	8·0	9·0	3·0
9	29·0	21·0	51·0	35·0	37·0	22·0	12·0	24·0	27·0	24·0
10	35·0	60·0	61·0	44·0	51·0	45·0	16·0	32·0	37·0	28·0
11	48·0	68·0	74·0	67·0	68·0	59·0	*Nil*	*Nil*	*Nil*	43·0
(Cumulative) 12	*Nil*	*Nil*	*Nil*	*Nil*	79·0	67·0	*Nil*	*Nil*	*Nil*	50·0
13	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	53·0
Total % harvested	48·0	68·0	74·0	67·0	79·0	67·0	16·0	32·0	37·0	53·0
Mean weight per fruit, lb	3·4	4·0	3·4	3·5	4·7	3·5	2·2	3·2	2·8	3·0

Table 2. (Plant crop)
(20 plants per plot. Suckers treated March 1952, 10 months after planting.)

Treatments in water	*'Hortomone A'*				*2,4-D*		*Acetylene*		*Control*
Concentration	0·25 *cm³*: 500 *cm³*	0·5 *cm³*: 500 *cm³*	0·75 *cm³*: 500 *cm³*	1·0 *cm³*: 500 *cm³*	2 *cm³*: 10 *gall*	2 *cm³*: 5 *gall*	2 *cm³*: 3 *gall*	1·5 *oz.*: 3 *gall*	3 *oz.*: 3 *gall*	
% Harvested at months after treatment 7	4·0	*Nil*	3·0	6·0	3·0	6·0	7·0	3·0	*Nil*	7·0
8	8·0	6·0	13·0	10·0	3·0	6·0	7·0	3·0	*Nil*	13·0
9	74·0	53·0	51·0	56·0	6·0	6·0	11·0	14·0	27·0	15·0
10	79·0	63·0	54·0	59·0	16·0	17·0	15·0	20·0	30·0	17·0
(Cumulative) 11	*Nil*	69·0	65·0	66·0	45·0	24·0	25·0	41·0	42·0	37·0
12	*Nil*	79·0	71·0	83·0	84·0	55·0	50·0	76·0	76·0	84·0
13	*Nil*	83·0	*Nil*	86·0	*Nil*	55·0	61·0	*Nil*	*Nil*	*Nil*
14	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	58·0	*Nil*	*Nil*	*Nil*	*Nil*
Total % harvested	79·0	83·0	71·0	86·0	84·0	58·0	61·0	76·0	76·0	84·0
Mean weight per fruit, lb	3·4	3·4	2·8	2·8	3·7	3·7	3·6	2·7	3·4	2·7

The results presented as *Table 2* show the superiority of ' Hortomone A' in accelerating the harvest, especially during the first three months. Though the lower ' Hortomone A' concentration had a tremendous influence on accelerating and shortening the harvest period, there was no favourable influence on the number of fruits produced. The 2,4-D and acetylene treatments increased fruit weight.

Trial III

This trial was put down to find out whether it would be possible to obtain 100 per cent fruiting from plants of uniform size when using growth-promoting substances. Though the plants were 16 months old at the time of treatment, they had originated from fruit crowns which had been cut up into eight vertical sections. Since fruit crowns can normally be expected to start flowering at about 14 months from planting, it was decided to treat the plants when 16 months old, even though they were considered immature.

The treatments were applied in January 1952, which coincided with the beginning of the dry, hot season. The Short Rains had been well distributed between October and December, totalling 11·37 in., and consequently the plants were well supplied with moisture at the time of the treatment. Only 1·97 in. of rain was recorded during the three months following treatment. Treatments in this trial were made by the cup method. A cup containing 80 cm^3 of the diluted substance was poured into the heart of each plant.

Table 3, which shows the results, indicates that the treatments were applied some five months before the time of natural flowering. The results also show that selected, uniform, immature plants produce a very short harvesting season and that it was possible to obtain 100 per cent fruiting.

All treatments exerted a tremendous influence on accelerating the harvest though there was a suppression of fruit weight. This suppression was greater in the ' Hortomone A' concentration at 1·0 cm^3 to 500 cm^3 of water when the influence on accelerating the harvest was greatest. The general suppression of fruit weight was probably the result of accelerating the fruiting of immature plants.

' Hortomone A' at the 1·0 cm^3 to 500 cm^3 of water strength had the most influence on accelerating the harvest when plants were well supplied with moisture at the time of treatment. The 2,4-D treatment also produced a favourable influence on accelerating the harvest. Acetylene had some influence on accelerating the harvest and also increased fruiting but fruit weight was suppressed.

Trial IV

The treatments were applied about the time of natural flowering to a First Ratoon Crop which originated from suckers. Treatments were made during May 1953, which was towards the end of the Long Rains. The plants were therefore well provided with moisture before treatment. The rainfall for the three months prior to treatment was 12·94 in. The rainfall for the three months after treatment totalled 3·31 in.

The shoots on each plant were reduced to two suckers before treating. The results which are shown in *Table 4* indicate the value of hormones on First Ratoon Crops. The ' Seradix A' treatment of 1·0 cm^3 to 500 cm^3,

Table 3. (Plant crop)
(7 plants per plot. Fruit top sections treated January 1952, 16 months after planting.)

Treatments in water	*'Hortomone A'*			*2,4-D*	*Acetylene*	*Control*
Concentration	0·25 *cm*³ : 500 *cm*³	1·0 *cm*³ : 500 *cm*³	1·5 *cm*³ : 500 *cm*³	2 *cm*³ : 3 *gall*	1·5 *oz.* : 3 *gall*	
% *Harvested at months after treatment* (*Cumulative*) 9	57·0	85·0	71·0	14·0	*Nil*	*Nil*
10	71·0	100·0	85·0	57·0	14·0	*Nil*
11	*Nil*	*Nil*	*Nil*	85·0	*Nil*	*Nil*
12	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*
13	*Nil*	*Nil*	100·0	*Nil*	*Nil*	*Nil*
14	*Nil*	*Nil*	*Nil*	*Nil*	85·0	57·0
15	86·0	*Nil*	*Nil*	100·0	*Nil*	*Nil*
16	*Nil*	*Nil*	*Nil*	*Nil*	100·0	85·0
Total % harvested	86·0	100·0	100·0	100·0	100·0	85·0
Mean weight per fruit, lb	3·3	2·4	3·1	3·0	2·6	3·4

Table 4. (First Ratoon crop)
(24 plants per plot. Suckers treated May 1953, 34 months after planting.)

Treatments in water	*'Planofix'*			*'Seradix A'*			*'Anapal'* *			*Control*
Concentration	0·25 *cm*³ : 500 *cm*³	0·5 *cm*³ : 500 *cm*³	1·0 *cm*³ : 500 *cm*³	0·25 *cm*³ : 500 *cm*³	0·5 *cm*³ : 500 *cm*³	1·0 *cm*³ : 500 *cm*³	1 *oz.* : 50 *oz.*	2 *oz.* : 50 *oz.*	3 *oz.* : 50 *oz.*	
% *Harvested at months after treatment* (*Cumulative*) 8	*Nil*	3·0	*Nil*	13·0	12·0	4·0	*Nil*	*Nil*	*Nil*	4·0
9	50·0	18·0	13·0	39·0	64·0	69·0	9·0	6·0	*Nil*	33·0
10	100·0	46·0	67·0	50·0	68·0	100·0	28·0	9·0	*Nil*	66·0
Total % harvested	100·0	46·0	67·0	50·0	68·0	100·0	28·0	9·0	*Nil*	66·0
Mean weight per fruit, lb	2·9	3·0	2·6	3·0	3·5	3·6	3·4	3·7	—	3·0

*Fluid oz.

which gave the best results in accelerating the harvest, also increased fruit weight. ' Planofix ', in the lower concentration, had a greater influence than the higher concentrations on accelerating the harvest and also increased the number of fruits though there was a slight suppression of fruit weight. 'Anapal ' had a very marked influence on suppressing the harvest, while fruit weight was favourably increased. The indications are that acceleration of harvesting may be possible by using lower concentrations of 'Anapal ' than were used in this trial.

Trial V

In Trial V the treatments were applied to a plant crop which had been planted 12 months previously. Treatments were made during April 1954, at the time of natural flowering. The planting material was composed of suckers. Rainfall during the three months before treatment was 5·80 in., and of this amount 3·17 in. had fallen during the eight days prior to treatment. During the three months following treatment 19·37 in. of rain was recorded.

In *Table 5*, which shows the results of the trial, the two lower concentrations of 1-naphthylacetic acid had the greatest influence on accelerating the harvest, especially during the first three months. Fruit weight was also increased.. ' Planofix ', ' Hortomone A' and the acetylene treatments all accelerated harvesting in varying degrees but, except for the ' Hortomone A' treatment at the 1·0 cm^3 to 500 cm^3 of water concentration, they did not increase the number of fruits. The 2,4-D and 'Tomato Set' treatments suppressed harvesting. 2,4-D at the two higher concentrations suppressed fruit weight.

The influence of ' Planofix ' in this trial shows the 0·75 cm^3 to 500 cm^3 in water concentration to be the most promising in accelerating the harvest.

Trial VI

The trial was treated in May 1955, when the plants were in the Second Ratoon. In this trial no shoot thinning was undertaken and the hormones were applied at the time of natural flowering. The rainfall during the three months before treatment totalled 10·66 in., and for the three months after treatment 4·41 in. was recorded. The results are presented in *Table 6*. As an accurate count of the number of shoots in each treatment was impossible due to density, the results are given as the cumulative number of fruits harvested and not, as in the previous trials, as the cumulative percentages. The plot size per treatment was based on the original planting of 99 plants per plot which was composed of fruit crowns.

All the treatments, except the higher 1-naphthylacetic acid concentration exerted considerable influence on accelerating the harvests especially during the second month, and on the number of fruits produced. There was, however, a marked suppression of fruit weight in all treatments. The most promising treatments were 1-naphthylacetic acid at a 1·5 g to 3 gall of water concentration and ' Hortomone A'.

DISCUSSION

The result of the trials shows conclusively that growth-promoting substances are capable of accelerating or retarding the harvesting of pineapples

Table 5
(Plant Crop)
(380 plants per plot. Suckers treated April 1954, 12 months after planting.)

Treatments in water		*'Hortomone A'*		*'Planofix'*				*1-Naphthylacetic acid*			*β-Indolyl-butyric acid*	*'Tomato Set'**			*2,4-D*			*Acetylene*		*Control*
Concentration		0·25 cm^3 : 500 cm^3	1·0 cm^3 : 500 cm^3	2·0 cm^3 : 1 *gall*	4·0 cm^3 : 1 *gall*	0·75 cm^3 : 500 cm^3	1·00 cm^3 : 500 cm^3	2 *g* : 3 *gall*	4 *g* : 3 *gall*	6 *g* : 3 *gall*	1 *g* : 2 *gall*	2oz. : 3 *gall*	3 oz. : 2 *gall*	16oz. : 2 *gall*	1 cm^3 : 3 *gall*	2 cm^3 : 3 *gall*	3 cm^3 : 3 *gall*	3 oz. : 3 *gall*	6 oz. : 3 *gall*	
% Harvested at months after treatment (Cumulative)	8	16·0	28·0	20·0	30·0	24·0	28·0	28·0	14·0	10·0	2·0	2·0	2·0	2·0	2·0	2·0	2·0	36·0	4·0	2·0
	9	42·0	60·0	38·0	55·0	52·0	50·0	70·0	68·0	54·0	14·0	8·0	10·0	16·0	8·0	14·0	4·0	44·0	24·0	10·0
	10	58·0	62·0	42·0	58·0	62·0	*Nil*	72·0	70·0	58·0	46·0	24·0	34·0	26·0	30·0	42·0	16·0	50·0	50·0	34·0
	11	64·0	73·0	43·0	60·0	65·0	58·0	76·0	72·0	62·0	59·0	54·0	54·0	45·0	41·0	48·0	40·0	68·0	60·0	58·0
	12	66·0	75·0	44·0	62·0	67·0	60·0	79·0	74·0	64·0	63·0	58·0	57·0	50·0	43·0	50·0	42·0	69·0	67·0	62·0
	13	68·0	82·0	49·0	64·0	68·0	63·0	*Nil*	79·0	75·0	74·0	60·0	59·0	57·0	46·0	51·0	44·0	72·0	68·0	74·0
Total % harvested		68·0	82·0	49·0	64·0	68·0	63·0	79·0	79·0	75·0	74·0	60·0	59·0	57·0	46·0	51·0	44·0	72·0	68·0	74·0
Mean weight per fruit, lb		2·6	2·7	2·7	2·7	2·5	2·7	3·1	3·2	3·0	3·0	3·1	3·1	3·0	3·0	2·7	2·7	3·1	3·1	3·0

*Fluid oz.

Table 6
(Second Ratoon crop)
(99 plants per plot. Fruit crowns treated May 1958, 49 months after planting.)

Treatments in water		*'Hortomone A'*	*'Planofix'*	*1-Naphthylacetic acid*		*Control*
Concentration		1·0 cm^3 : 500 cm^3	0·75 cm^3 : 500 cm^3	1·5 *g* : 3 *gall*	2·0 *g* : 2 *gall*	
Number of fruit harvested at months after treatment (Cumulative)	8	20	21	13	9	15
	9	81	68	54	21	30
	10	136	121	140	85	39
	11	145	122	171	136	42
Mean weight per fruit, lb		2·1	2·0	2·0	1·1	3·1

as Plant crop and Ratoon crops. In the Plant and First Ratoon crops, fruit size was increased with certain treatments and there was also a tendency to increase the number of fruits. 100 per cent fruiting was achieved from a First Ratoon crop and from immature, selected uniform plants of a Plant crop as a result of treatment (see *Tables 3* and *4*). The Second Ratoon crop responded equally well with regard to acceleration of harvesting but there was a most suppressing influence on fruit weight. This suppression was counteracted by the greater number of fruits produced when compared with the nil treatment. Moreover, as the Second Ratoon plants had not been thinned, large numbers of inferior and premature shoots were induced to produce fruits of small size which resulted in a considerable reduction of the mean fruit weight. When Ratoon crops are controlled by shoot thinning, it is unlikely that fruit weight would be suppressed as a result of favourable hormone treatments.

Of the treatments used in the trials, 1-naphthylacetic acid at a concentration of 2·0 g to 3 gall of water is considered the most promising for use on a Plant crop if applied at a time when plants are not well supplied with moisture. When this concentration was used on plants of a Second Ratoon crop, which were well supplied with moisture at the time of treatment, a concentration of 1·5 g to 3 gall of water proved to be the best.

The influence of ' Hortomone A' on a Plant crop was found to vary according to the amount of moisture available at the time of treatment. The results show that the higher concentration at 1·0 cm^3 to 500 cm^3 of water was more effective when the plants were well supplied with moisture at the time of treatment and that the lower concentration of 0·25 cm^3 in 500 cm^3 of water was the best when plants were less well provided with moisture. ' Hortomone A' was also highly effective when used on a Second Ratoon crop.

' Seradix A' at a concentration of 1·0 cm^3 to 500 cm^3 of water had a tremendous influence on accelerating the harvest of a First Ratoon crop and also on the number of fruits produced. The higher concentration had the greatest influence when the treatment was applied at a time when the plants were well supplied with moisture. The result may indicate that lower concentrations will be most effective when applied to plants which are less well provided with moisture.

' Planofix ' also produced promising results with regard to accelerating the harvest of a Plant crop and a First and Second Ratoon crop. The best results from ' Planofix ' were achieved on the First Ratoon crop when the hormone was used at a concentration of 0·25 cm^3 to 500 cm^3 of water. Since the plants were well supplied with moisture at the time of treatment, and when comparing the influence of ' Planofix ' in the same concentration on a Plant crop (see *Table 5*), which was applied when the plants were less well supplied with moisture, the indications are that a slightly lower concentration is likely to be more effective when applied to plants which are not well provided with moisture, as was the case with the 1-naphthylacetic acid and ' Hortomone A' treatments.

β-Indolylbutyric acid is promising when used at a concentration of 0·5 g to 500 cm^3 of water. Harvesting of a Plant crop was accelerated and the number of fruits, as well as mean fruit weight, was increased. When used

on a Plant crop in a lower concentration and when the plants were less well supplied with moisture, the result was disappointing.

The acetylene treatment which showed most promise, when applied to a Plant crop, was at a concentration of 3·0 oz. to 3 gall of water. This result was achieved when plants were not well provided with moisture at the time of treatment. A concentration of 1·5 oz. to 3 gall of water applied to immature plants, well supplied with moisture at the time of treatment, had little influence. It is possible that a higher concentration of acetylene may be necessary when applied to plants well provided with moisture.

'Anapal', 'Dicotox', 2,4-D and 'Tomato Set' all tended to exert a suppressing influence on harvests. 'Anapal' showed an increasing suppression on the harvests as the concentration increased. The indications are that a concentration well below the 1·0 oz. to 50 oz. of water is likely to be more useful for the purpose of accelerating the harvest of a First Ratoon crop when plants are well provided with moisture. 'Dicotox' at the higher concentration of 1·0 cm^3 to 500 cm^3 of water, while exerting a slight influence on accelerating the harvest of a Plant crop, had a marked influence on suppressing fruiting. It is possible that even higher concentrations may be required, under similar conditions, to accelerate harvesting and increase fruiting. The 2,4-D failed to accelerate fruiting of a Plant crop or to increase the number of fruits produced but, in Trial II, there was an increase in the mean fruit weight. When applied to an immature Plant crop (see *Table 3*) when the plants were well provided with moisture, acceleration of the harvest was tremendous. The suppression of fruit weight was to be expected in view of the fact that the treatment was applied to immature plants. 'Tomato Set' suppressed the harvests and fruiting though there was a slightly favourable influence on mean fruit weight.

Whether the cup method of applying growth-promoting substances is superior to the spray method has not been proved insofar as its influence on the acceleration of fruiting is concerned. The results of the method, as given in *Table 3*, show that acceleration of fruiting by means of the two best 'Hortomone A' treatments is greater than in any of the other trials. This result, however, is considered to have been produced not only because of suitable hormone treatment but also because the plants were selected, uniform and immature. Even if it had been proved that the cup method was superior in accelerating fruiting, there would still be a great deal in favour of the spray method. This method not only eliminates the laborious task of treating each plant separately, but also greatly reduces the amounts of growth-promoting substance and water to be used.

Though it was found that immature plants also responded favourably to hormone treatments, the treatment of immature plants will require careful consideration. It may be unwise to treat plants more than two months before the time of natural flowering.

The cost of growth-promoting substances is not considered to be high when their potential value is realized. The cost of 1-naphthylacetic acid at the higher concentration would be about 25*s* per acre. Hormones which are sold under trade names would cost much more. If, however, the amount of diluted hormone per plant by the spray method, i.e. 40 cm^3, could be reduced, then a reduction in the cost of the hormone per acre would result.

SUMMARY

1-Naphthylacetic acid, ' Hortomone A', ' Seradix A' and ' Planofix ' all exerted a tremendous influence on fruiting and harvesting of pineapples. An increased number of plants was induced to produce fruit and harvesting was accelerated. Fruit weight was also increased but when immature plants were treated, fruit weight was suppressed. The 2,4-D exerted a suppressing influence on fruiting and retarded harvesting. When applied to immature plants, fruiting was increased and harvesting accelerated but fruit weight was suppressed. ' Dicotox ' suppressed fruiting and harvesting but fruit weight was increased. 'Anapal ' and ' Tomato Set ' also suppressed fruiting. β-Indolylbutyric acid and acetylene, though promising, require further trial.

The influence of the treatments when applied at different seasons, indicates that higher concentrations are required during the rains, or when plants are well supplied with moisture, than are required before the rains or when plants are less well provided with moisture.

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REFERENCES

Cannon, B. C. (1955). ' Can Black Heart of pineapples be avoided? ' *Qd. agric. J.* **81**, Dec.
Harland, S. C. (1953). ' Plant hormones.' *J. R. hort. Soc.* **78**, May
Malan, E. F. (1954). ' Pineapple production in South Africa.' *Fmg in S. Afr.* **29**, May, No. 338

The Effect on Groundnuts (Arachis hypogea) *of Pre-emergence Applications of MCPB*

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The development of 4–(4–chloro–2–methylphenoxy)butyric acid (henceforth referred to as MCPB) as a selective weedkiller has largely arisen as a result of work concerned with relating chemical structure to growth-regulating activity (Fawcett *et al.*, 1953 and 1955; Wain, 1951 and 1955; Wain and Wightman, 1954), and it is recognized that its herbicidal action depends upon degradation of the alkylcarboxylic acid side chain by β-oxidation. The use of MCPB and closely related compounds in relation to temperate weeds and crops has been discussed by Carpenter and Soundy (1954), Wain (1954) and Kerkin and Peters (1957) but there are few, if any, published reports of its use in the tropics. Morris (1956) working at the Imperial College of Tropical Agriculture in Trinidad carried out non-replicated preliminary field trials to test the response of various tropical crops to the application of doses of MCPB and reported that maize (*Zea mays*), cowpea (*Vigna sinensis*), groundnut (*Arachis hypogea*), soya bean (*Glycine soja*) and sorghum (*Sorghum vulgare*) showed signs of tolerance to the application of MCPB as a pre-emergence spray applied on the day of planting, whilst rice (*Oryza sativa*), sesame (*Sesamum indicum*) and cotton (*Gossypium hirsutum*) appeared to be very sensitive to such applications. Morris also reported that rice, maize and sorghum appeared very tolerant of applications of MCPB made three weeks after emergence and that groundnut showed reasonable tolerance of applications made at this time. He observed that pre-emergence applications of MCPB prevented the appearance of *Amaranthus* spp. and *Commelina* spp. for a period of three weeks and considerably suppressed the development of *Brachiaria mutica* (Forsk) Stapf., *Cynodon dactylon* (L.) Pers. and *Paspalum fasciculatum* Willd. which began to appear after about 30 days. *Cyperus rotundus* L. was little affected by the spray. Post-emergence application of MCPB gave less control of weeds; *Amaranthus* spp. were killed, *Commelina* spp. were suppressed, but grasses were not visibly affected. The work reported below was also carried out at the Imperial College of Tropical Agriculture and was designed to investigate, more fully, the response of groundnuts (*Arachis hypogea*) to various doses of MCPB applied between planting and emergence.

METHODS

The first phase of the work consisted of a trial in which spray applications were made to groundnuts sown in boxes with dimensions 18 in. × 17 in. × 4 in. These boxes were filled with a thoroughly mixed and then sieved soil obtained from the top 6 in. of a soil-type classified by Chenery (1952) as

St Augustine loam. After the soil had been moistened by placing the boxes for a short time in large metal trays containing water, each was planted with 25 seeds of South African bunch groundnuts spaced 3 in. apart on the square. The spray was applied by placing the boxes upon a conveyor which carried them at constant speed beneath a carefully calibrated Duiker Lionette nozzle fed from an Oxford Precision Sprayer. The volume applied was equivalent to 49·5 gallons per acre, due allowance having been made for lack of uniformity of spray distribution across the width of the wetted area. Subsequently the boxes were kept in metal trays and water provided, when required, by sub-irrigation, except in some instances when water was applied to the surface as an experimental treatment. The trays holding the boxes were housed in an open-sided building with a roof consisting of two thirds glass and one third corrugated aluminium. Once per week 5g (approximately) sulphate of ammonia was applied to each box and BHC dust was regularly applied as a routine precautionary measure. Results were assessed by making germination counts, by regular inspection for signs of spray damage, and by sampling three weeks after spraying followed by dry-weight determinations. In determining dry weights, plants were cut off at ground level, and dried for 24 hours at a temperature of 105 to 110°C.

In the second phase of the work, a trial was carried out to confirm that the findings of the box experiments applied in the field. Groundnuts were planted, by hand, in plots which were subsequently sprayed by making timed applications with an Oxford Precision Sprayer fitted with four Allman flat-fan type ceramic nozzles. Results were assessed by means of germination counts, by means of regular observations of the health of the plants and from the yield of air-dried nuts weighed in the shell.

AN EXPERIMENT TO DETERMINE THE EFFECTS ON GROUNDNUTS GROWN IN BOXES OF APPLICATIONS OF MCPB MADE BEFORE CROP-EMERGENCE

Morris (1956) reported that no deaths were caused by applying up to 15·0 lb/acre MCPB to groundnuts on the day of planting but noted that doses of $3\frac{3}{4}$ lb/acre or more caused damage so severe that full recovery appeared unlikely.

Using this information, the first experiment carried out was designed to measure the tolerance of groundnut plants to pre-emergence applications of sodium MCPB made at different times and under varying conditions of both ' water applied to the surface ' and ' planting depth '. The treatments used were as follows:

(*a*) Dose of sodium MCPB:	0·16 lb/acre active ingredient
	0·38 „ „ „
	0·94 „ „ „
	2·25 „ „ „
	5·53 „ „ „
(*b*) Depth of planting:	Shallow ($\frac{1}{2}$ in.)
	Deep (2 in.)
(*c*) Time of spraying:	On day of planting
	3 days after planting
(*d*) Surface watering on day of spraying:	None (0 in.)
	Light ($\frac{1}{2}$ in.)
	Heavy ($2\frac{1}{2}$ in.)

These treatments were combined in two replications of the 60 treatment combinations and a ' plot ' consisted of two standard boxes each containing 25 seeds spaced 3 in. apart on the square.

After spraying, the boxes were housed in the open-sided building, and for administrative convenience were grouped in two major sets according to the time of spraying, but were fully randomized within each set. The inclusion of ' no spray ', as a treatment level in the dose factor, although in many ways desirable, leads to complications in the analysis of variance arising from the presence of ' dummy ' treatments in the interaction with the ' time of spraying ' factor. However, a series of boxes which received no MCPB were subjected to all combinations of the factors ' depth of planting ' and ' application of water to the surface ' respectively, and a complete group of each was distributed at random within each of the ' time of spraying ' sets to which reference has already been made. These boxes were observed and sampled with the rest, although the results therefrom have not been included in the various analyses of variance.

The seeds were planted by pushing them gently into moist soil to the requisite depth. The method was not ideal as although the depressions were subsequently filled the compaction in the vicinity of the seeds probably channelled the applied surface water towards the seed.

The boxes were then sprayed by placing them on the conveyor already described and, immediately afterwards, were transferred to the metal trays in the open-sided building and were not moved again throughout the experiment.

Where required, appropriate amounts of water were applied to the surface of the boxes from a watering can fitted with a fine rose. In those instances where $2\frac{1}{2}$ in. of water was needed the application was extended over a period of approximately four hours to prevent run-off. For the same reason, applications of water equivalent to $\frac{1}{2}$ in. ' rainfall ' were applied over a period of approximately one hour. It was observed, nevertheless, that application of $2\frac{1}{2}$ in. water caused severe capping of the soil surface.

Seventeen days after planting, counts were made of the numbers of plants germinated and at three weeks after emergence an estimate of the mean dry weight per plant was obtained from a sample of five plants taken from each of the boxes. In the five instances in which less than the requisite number of plants remained after three weeks the mean dry weight per plant was estimated from the survivors.

Results

It was observed that doses of 2·25 and 5·53 lb/acre caused visible morphological effects which were small at the lower dose but very marked at the higher dose. Plants tended to be stunted and suffered from corky lesions of the stem. Entire plants were stiffer and more leathery to handle and some of the early formed leaves remained reduced in size and became spatulate rather than elliptic. Such spatulate leaves often displayed a mottling of light and dark green in various patterns, usually the darker colour being more distal and peripheral, the lighter proximal and central with a mottled zone between. The leaf margin was also affected, being crinkled or rolled down.

An outstanding feature of the other effects was that those applied treatments which reduced germination also tended to reduce the dry weight per plant at three weeks after germination. This can be seen from the summarized effects of the main treatments which are shown in *Tables 1* to *4*.

Table 1. Effect of dose of MCPB (applied before emergence) upon germination of groundnuts and dry weight per plant at three weeks

Dose of sodium MCPB lb/acre	*Germination*		*Plant dry wt at 3 weeks*	
	No. germinated	*Expressed as % of germination in controls*	*Dry wt per plant g*	*Expressed as % of dry wt of controls*
0·16	783	89	0·773	88
0·38	742	84	0·772	88
0·94	720	82	0·597	68
2·25	613	70	0·640	73
5·53	529	60	0·464	53
Least sig. diff. P=0·05	129·2	—	0·093	—
Least sig. diff. P=0·01	169·8	—	0·123	—

The controls consisted of a set of 24 boxes arranged in groups of four of which each group received one of the six possible combinations of planting depth and surface watering.

Table 2. Effect of time of spraying MCPB on germination of groundnuts and dry weight per plant at three weeks

Time of spraying	*Germination*		*Plant dry wt at 3 weeks*	
	No. germinated	*Expressed as % of germination in controls*	*Dry wt per plant g*	*Expressed as % of dry wt of controls*
Same day as planting	1255	57	0·589	67
Three days after planting	2132	97	0·709	81
Least sig. diff. P=0·05	204·2	—	0·059	—
Least sig. diff. P=0·01	268·8	—	0·078	—

The controls consisted of a set of 24 boxes arranged in groups of four of which each group received one of the six possible combinations of planting depth and applied surface water.

From inspection of these tables it is clear that both germination and subsequent development were affected:

(*a*) by the applied dose of MCPB

(*b*) by the time of application of the chemical and

(*c*) by the application of surface water on the day of spraying.

Table 3. Effect of surface watering on day of spraying MCPB, on germination of groundnuts and dry weight per plant at three weeks

Surface watering	*Germination*	*Dry weight*
	No. germinated	*Mean wt per plant at 3 weeks g*
None	1286	0·708
Light (½ in.)	1185	0·687
Heavy (2½ in.)	916	0·553
Least sig. diff. P=0·05	166·8	0·072
Least sig. diff. P=0·01	219·6	0·095

Table 4. Effect of depth of planting (in presence of applied doses of MCPB) upon germination of groundnuts and dry weight per plant at three weeks

Depth of planting	*Germination*	*Dry weight*
	No. germinated	*Mean wt per plant at 6 weeks g*
½ in.	1723	0·668
2 in.	1664	0·631

Differences due to treatment are not significant.

The depth of planting appears to have exerted little influence upon the results, but further inspection shows that there was considerable interaction between the main treatments, and those which, on analysis, proved to be statistically significant are shown in *Tables 5* to *7* inclusive.

Table 5. Effect of interaction between dose and time of application of MCPB on dry weight of groundnut at three weeks

		Dose of sodium MCPB lb/acre				
		0·16	0·38	0·94	2·25	5·53
Time of spraying	*On day of planting*	0·742 (85%)	0·683 (78%)	0·480 (55%)	0·662 (76%)	0·380 (43%)
	3 days after planting	0·805 (92%)	0·860 (98%)	0·713 (81%)	0·618 (71%)	0·548 (63%)

Least significant interaction=0·132 g (P=0·05)

The data shown are dry weights per plant in grammes. Numerals in parentheses represent the value above expressed as percentage of mean response of a set of controls which received no spray but all combinations of 'depth of planting' and 'surface watering'.

The interaction between the dose of MCPB and its time of application had no significant effect upon germination, but produced a significant response ($P=0·05$) in the dry matter per plant at three weeks after emergence.

It is difficult to decide what reliance can be placed upon this, however, as inspection of *Table 5* shows that although the overall response to increasing the dose of MCPB appears to be slightly greater when the spray is applied on the day of planting, the only significant comparisons depend upon the fact that the dry weight per plant associated with the application of 0·94 lb/acre on the day of planting is abnormally small in relation to the other observations.

Table 6. Effect of interaction between ' dose of MCPB ' and ' surface watering on day of spraying ' on germination of groundnuts and mean dry weight per plant at three weeks

Surface watering	*Dose of sodium MCPB lb/acre*					
	0·16		0·38		0·94	
	No. germinated	*Dry wt at 3 wks g*	*No. germinated*	*Dry wt at 3 wks g*	*No. germinated*	*Dry wt at 3 wks g*
None	283 (97%)	0·768 (90%)	255 (87%)	0·733 (86%)	269 (92%)	0·648 (76%)
Light ($\frac{1}{2}$ *in.*)	305 (97%)	0·805 (83%)	283 (90%)	0·983 (101%)	200 (64%)	0·548 (56%)
Heavy ($2\frac{1}{2}$ *in.*)	195 (71%)	0·748 (93%)	204 (75%)	0·600 (75%)	251 (92%)	0·595 (74%)

Least significant interaction (germination) = 74·60 *g* (*P* = 0·05)
Least significant interaction (dry weight) = 0·162 *g* (*P* = 0·05)

Surface watering	*Dose of sodium MCPB lb/acre*			
	2·25		5·53	
	No. germinated	*Dry wt at 3 wks g*	*No. germinated*	*Dry wt at 3 wks g*
None	226 (77%)	0·748 (88%)	253 (87%)	0·643 (76%)
Light ($\frac{1}{2}$ *in.*)	212 (68%)	0·708 (73%)	185 (59%)	0·393 (40%)
Heavy ($2\frac{1}{2}$ *in.*)	175 (64%)	0·465 (58%)	91 (33%)	0·358 (44%)

Numerals in parentheses represent the observation above expressed as a percentage of controls which received no spray but were otherwise treated the same as the boxes from which the particular observation was obtained.

The interaction between dose of MCPB and ' surface watering on the day of spraying ' had a significant effect ($P = 0·01$) upon both germination and the dry weight per plant measured three weeks after germination. This can be seen by reference to *Table 6* which shows, in general, that increasing the dose of MCPB from 0·16 to 5·53 lb/acre in the absence of surface watering caused only a relatively small decrease in the germination and subsequent dry weight at three weeks, whereas increasing the applied dose through the same range occasioned a much larger crop response when either $\frac{1}{2}$ in. or $2\frac{1}{2}$ in. of water was applied to the soil surface on the day of spraying.

Other individual comparisons within *Table 6* demonstrate significance but this trend constitutes the outstanding feature of the interaction.

Table 7. Effect of interaction between 'depth of planting' and 'surface watering on day of spraying' on germination of groundnuts and mean dry weight per plant at three weeks

Surface watering	*Planting depth* ½ *in.*		2 *in.*	
	No. germinated	*Dry wt at 3 weeks g*	*No. germinated*	*Mean dry wt at 3 wks g*
None	621 (82%)	0·774	665 (95%)	0·641
Light (½ *in.*)	534 (64%)	0·616	651 (90%)	0·758
Heavy (2½ *in.*)	568 (90%)	0·613	348 (45%)	0·498

Least significant interaction (*germination*) = 117·93 (P = 0·05)

Least significant interaction (*dry weight*) = 0·102 *g* (P = 0·05)

Numerals in parentheses represent the observation above expressed as a percentage of controls which received no spray but were otherwise treated the same as the boxes from which the observation was obtained.

The effect of the interaction between planting depth and surface watering on both germination and plant dry weight proved to be significant (P = 0·01) and the results are summarized in *Table 7*, but when considering the results shown in this table it must be borne in mind that all the plants under observation received some dose of MCPB within the range 0·16 to 5·53 lb/acre. The outstanding feature shown is that deep planting differs little from shallow planting in the absence of surface watering, shows to slight advantage in the presence of light surface watering (½ in.), but shows to a very considerable disadvantage in the presence of heavy surface watering (2½ in.).

Discussion

From the results of this experiment it is concluded that the tolerance of groundnuts to the pre-emergence application of MCPB is conditioned by the time of spraying; the crop is much less affected by doses applied three days after planting than by doses applied on the day of planting. The response of the crop is also conditioned by the application of water shortly after spraying. If no water falls on the soil surface the crop is little affected, even by relatively heavy doses of MCPB. Light watering considerably increases the susceptibility of seed planted ½ in. deep but has little effect upon the response of seed planted 1 in. deep. Heavy watering, on the other hand, has little effect upon the response of shallow planted seed, but has a very considerable effect upon the response of seed planted 2 in. deep.

The effect of the combination of deep planting and heavy watering is particularly severe and appears to depend upon the presence of MCPB. This is inferred from the mean response of deep planted and heavily watered seeds which received doses of MCPB, when compared with the response of seeds which received no dose of MCPB but were similarly planted and watered. This particular comparison has not been subjected to statistical

treatment, but the response is so large (e.g. 51 per cent loss in germination) that there can be little doubt of its being real.

It appears, therefore, that anything which tends to place the active material in contact with the seed at the time when the process of germination is initiated increases the susceptibility of groundnuts to pre-emergence applications of MCPB, and this seems very reasonable in view of the recognized mode of action of this chemical and its dependence for activity upon the process of β–oxidation. It is also apparent that in circumstances in which no rain falls for an appreciable time after the application of the spray, the tolerance of the crop will tend to be exaggerated.

However, from results obtained from boxes it seems that, irrespective of rainfall, 1·0 to 2·0 lb/acre sodium MCPB may be applied safely to groundnuts three days after sowing provided care is taken to avoid very deep planting. Further work is required to confirm this and it is suggested that these findings might be used as a basis for the design of field experiments.

A FIELD EXPERIMENT ON THE EFFECT ON GROUNDNUTS OF APPLICATIONS OF MCPB MADE BEFORE EMERGENCE

This experiment was designed to test, in the field, the conclusions reached from the trial carried out in boxes and the treatments used were as follows:

Not weeded					
Hand weeded					
10·0 lb/acre	(active ingredient)			Ammonium dinoseb	
1·0	,,	,,	,,	Sodium MCPB	
2·0	,,	,,	,,	,,	,,
3·0	,,	,,	,,	,,	,,

Six replications of these treatments were used in a randomized block design with the blocks arranged in pairs on each of three cambered beds, 270 ft long and 30 ft wide, separated from each other by box drains. The experiment was located upon a soil type classified by CHENERY (1952) as River Estate Fine Sand. Seeds of South African bunch groundnuts were planted by hand 1 in. deep and 4 in. apart in ridges 6 in. to 8 in. high and 2 ft wide running across the beds in plots of size 0·0066 acre separated from each other by 2 ft. Two days before planting each plot received 3 lb of a mixture of equal parts by weight of sulphate of ammonia, muriate of potash and triple superphosphate.

All spray treatments were applied three days after planting using an Oxford Precision Sprayer. The use of ammonium dinoseb (ammonium salt of 4,6–dinitro–*o*–*sec*–butylphenol) followed the recommendations in the *Report* of the Research Committee of the Southern Weed Control (1957) Conference. The selection of the doses of MCPB was governed by the results of the trial previously described and the highest dose was chosen to be a little higher than the limit of expected crop tolerance. The dinoseb was applied in a total volume equivalent to 88 gallons per acre, but all doses of MCPB were applied in a total volume equivalent to 22 gallons per acre. On the fourth day after spraying, approximately 1 in. of irrigation water was applied in three hours through an overhead irrigation system and further irrigation water was applied as required. The crop was grown during one of the most severe dry seasons recorded in Trinidad.

Emergence of the crop was rather slow both in sprayed and unsprayed plots, the first plants appearing in eight days and plants continuing to emerge for a further period of 14 days. Emergence in all plots, including those not sprayed, was very poor and two weeks after sowing seeds were dug from the guard-rows in an attempt to investigate the cause. It was found that in some instances there were no signs of germination and the seeds were covered in a green mould (*Penicillium* spp.), whereas in other instances the radicle had been extended and then attacked by a black mould (*Aspergillus niger*).

Results

The results were assessed from the numbers of plants emerged at three weeks after sowing, by scoring for weed control at four weeks, by assessing the period of time for which weed control remained effective and from the yield of nuts. These results are summarized in *Table 8*.

Table 8. Effect on groundnuts and weeds of applications of MCPB made three days after sowing

	Observations			
	(*i*)	(*ii*)	(*iii*)	(*iv*)
Treatments	*Groundnuts emerged after 3 weeks*	*Mean weed score 4 wks after spraying 0=no weeds 10=infested*	*Period of effective weed control*	*Yield lb/acre of nuts sun-dried in shell*
Not weeded	425	9·3	—	88
Hand weeded as required	414†	9·3*	—	570
10·0 *lb/acre dinoseb*	465	0·0	*Until harvest*	730
1·0 *lb/acre MCPB*	497	5·3	50 *days (approx.)*	725
2·0 *lb/acre MCPB*	414	4·1	50 *days (approx.)*	679
3·0 *lb/acre MCPB*	363	3·1	50 *days (approx.)*	674
Least sig. diff. P=0·05	*Not significant*	—	—	179 *lb/acre*
Least sig. diff. P=0·01	*Not significant*	—	—	242 *lb/acre*
Coefficent of variation	20%	—	—	26%

* Weed score made just before hand weeding.
† Not included in analysis of variance. Treatment fictitious at this stage of crop growth.

Statistical analyses followed by application of an *F* test to the treatments variance failed to demonstrate significant differences between the numbers of plants which emerged. However, by subdivision of the treatments sum of squares into a set of orthogonal single components it has been shown that the number of plants which emerged after the application of 3·0 lb/acre MCPB

is significantly less ($P=0{\cdot}05$) than the mean number which emerged in all other plots. Likewise, it has been shown that the mean emergence in plots sprayed with either dinoseb, 1·0 or 2·0 lb/acre MCPB does not differ significantly from that of the controls. It is appreciated that discretion must be used in singling out individual comparisons in this way, but the method is justified by the fact that all treatments other than the application of 3·0 lb/acre MCPB were chosen because there was evidence to suggest that the groundnuts would not be affected. The results from the plots scheduled for hand weeding were not included in the analysis of variance of emergence as the treatment, at this stage, was fictitious. An outstanding feature of the results, not shown by the data in *Table 8*, is that in no plot did more than 25 per cent of the planted seeds emerge.

The crop was harvested 16 weeks after planting and the effect of the treatments upon yield proved to be highly significant ($P=0{\cdot}01$), but this is almost entirely due to the extremely poor yield obtained from those plots in which weed growth was allowed to develop completely unchecked. None of the other treatments differed significantly between themselves in their effects upon the yield, although the differences between:

(*i*) hand weeding and the application of 10·0 lb/acre dinoseb and

(*ii*) hand weeding and the application of 1·0 lb/acre MCPB

both approached significance. The yields, in general, are extremely low in relation to normal and this is, largely, a reflection of the poor germination.

The effect of the sprays upon weed control was most marked. The values (which are means of 6) in column (*ii*) of *Table 8* were arrived at by allocating a mark for weediness in each plot. 0 was awarded if no weeds were found in the plot and 10 if the plot was considered to be heavily infested with weeds. Following the application of 10 lb/acre dinoseb, weeds were entirely absent from the plots at four weeks after spraying and remained absent until harvest. Applications of 1·0, 2·0 or 3·0 lb/acre MCPB considerably reduced weed competition during the early stages of crop growth, but by 50 days after spraying it was judged that weed growth was offering serious competition to the crop, and weeds were removed by hoeing. This weeding was confined to the inter-rows to avoid interruption of the pegging of the crop. The principal weeds present in unsprayed plots were the grasses, *Eleusine indica* (L.) Gaertn., *Eriochloa punctata* (L.) Desv., *Chloris radiata* L. and *Panicum fasciculatum* Swartz.

Discussion

The poor germination obtained throughout all treatments in this experiment is not readily explained, as pre-planting germination tests carried out in Petri dishes showed 85 per cent of the seed to be viable. As a result of the inadequate stand obtained in the field the results must be considered inconclusive, but tend to confirm that groundnuts will tolerate doses of MCPB of the order of 2·0 lb/acre applied three days after planting although the effect upon emergence suggests that 3·0 lb/acre is probably excessive. However, the rainfall conditions after spraying were such that crop tolerance would have been at its highest. The control of weeds obtained from 2·0 lb/acre MCPB proved to be fair in the particular conditions of this experiment in which annual grass weeds predominated, and hand weeding was

not required until seven weeks after spraying. In effect, this was equivalent to a saving of one hand-weeding throughout crop growth. The control of weeds obtained by the application of 10·0 lb/acre ammonium dinoseb was not only more complete but more persistent and the crop required no hand weeding between planting and harvest. However, the dinoseb is much more difficult and unpleasant to handle.

CONCLUSIONS

The preliminary field trials (Morris, 1956), from which it was inferred that groundnuts showed an appreciable tolerance to MCPB applied three days after planting, were carried out in circumstances in which, by chance, no rain fell for a period of three days after the application of the spray. From subsequent findings, it is now clear that this constitutes a condition in which groundnut is likely to exhibit a high level of tolerance to the herbicide and it now appears that MCPB is less satisfactory for use as a pre-emergence weed-killer in groundnut than was originally hoped.

It is not intended that field recommendations be made on the basis of information obtained from these experiments. In this series, the field experiment was not particularly satisfactory but, at best, the results of a single field experiment are mainly of local application and severely limited by the climatic conditions which happen to prevail. However, sufficient information is available to show that:

(*i*) about 2 lb/acre MCPB can safely be applied to groundnuts three days after planting;

(*ii*) the crop is less affected by sprays applied three days after sowing than by sprays applied on the day of sowing;

(*iii*) doses greater than 2 lb/acre which have little effect upon the crop in the absence of rainfall will cause serious damage if rain falls shortly after sowing;

(*iv*) the level of general weed control obtained from the application of 2 lb/acre MCPB is likely to be less satisfactory than the control which could be obtained by the application of 10 lb/acre dinoseb but the cost of material will be less and the handling problems considerably reduced.

It is hoped that this information may be of use in showing the potential value of pre-emergence applications of MCPB for the control of weeds in groundnuts, and also be of value in the planning and interpretation of experiments intended to test its efficiency in any particular locality.

From observations (not subjected to statistical treatment) made upon these and other experiments it is considered that the following weed species would be largely controlled by the application of 2·0 lb/acre MCPB made before the weeds appeared:

Euphorbia hirta L., *Euphorbia hypericifolia* L., *Amaranthus* spp., *Portulaca oleracea* L., *Phyllanthus* spp., *Merremia aegyptia* (L.) Urban, *Commelina* spp.

Some suppression of the following weeds may also be achieved:

Eleusine indica (L.) Gaertn., *Eriochloa punctata* (L.) Desv., *Chloris radiata* (L.) Swartz, *Panicum fasciculatum* Swartz, *Brachiaria mutica* (Forsk) Stapf., *Cynodon dactylon* (L.) Pers., *Paspalum fasciculatum* Willd.

The following weed species appear to be virtually unaffected by application of 2·0 lb/acre MCPB made before germination:

Cleome aculeata L., *Mimosa pudica* L., *Alternanthera* spp., *Caperonia palustris* (L.) St. Hil., *Spigelia anthelmia* L., *Rottboellia exaltata* (L.) Kuntze.

SUMMARY

A series of experiments concerned with the effect upon groundnuts of MCPB is described, commencing with work in observation plots, followed by studies in a greenhouse and completed by an experiment conducted in the field.

From the germination and subsequent increase in dry matter of groundnuts planted in boxes it is shown that the crop is more affected by doses of MCPB applied on the day of planting than by similar doses applied three days after planting, and that crop damage is most severe when light rain falls shortly after spraying seed which has been planted ½ in. deep or when heavy rain falls after spraying seed planted 2 in. deep. It is concluded that 2 lb/acre MCPB can be applied to groundnuts three days after sowing and this conclusion is supported by the effect upon crop yield of various doses applied in a field experiment.

A list is given of the weed species likely to be controlled or suppressed by the pre-emergence application of 2 lb/acre MCPB.

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REFERENCES

Wain, R. L. (1951). ' Plant growth-regulating and systemic fungicidal activity: the aryloxyalkylcarboxylic acids '. *J. Sci. Fd Agric.* **2,** 101–106

Fawcett, C. H., Osborne, D. J., Wain, R. L. and Walker, R. D. (1953). ' Side-chain structure in relation to growth-regulating activity in the aryloxyalkylcarboxylic acids'. *Ann. appl. Biol.* **39,** 231–243

Wain, R. L. and Wightman, F. (1954). ' The growth-regulating activity of certain ω–substituted alkylcarboxylic acids in relation to their β-oxidation within the plant'. *Proc. Roy. Soc. B,* **142,** 525

Wain, R. L. (1955). ' A new approach to selective weed control '. *Ann. appl. Biol.* **42,** 151–157

Fawcett, C. H., Wain, R. L. and Wightman, F. (1955). ' The growth-promoting activity of certain aryloxy-and arylthio-alkanecarboxylic acids '. *Ann. appl. Biol.* **43** (3), 342–354

Carpenter, K. and Soundy, M. (1954). ' Investigations into the practical value of MCPB as a selective weedkiller in leguminous crops '. *Proc. Brit. Weed Control Conf.* **1,** 327–345

Wain, R. L. (1954). ' Selective weed control. Some new developments at Wye '. *Proc. Brit. Weed Control Conf.* **1,** 311–317

Kerkin, A. J. and Peters, R. A. (1957). ' Herbicidal effectiveness of 2,4–DB, MCPB, Neburon and other materials as measured by weed control and yields of seedling alfalfa and birdsfoot trefoil '. *Proc. Northeastern Weed Control Conf.* 128–138

Morris, R. L. (1956). ' Preliminary investigations into the use of chloroacetamides and MCPB as herbicides in the tropics '. *D.T.A. Rep.* (Unpublished). Imperial College of Tropical Agriculture, Trinidad, West Indies

Chenery, E. M. (1952). *The Soils of Central Trinidad.* Government Printing Office, Trinidad, West Indies

' Report of Research Committee ' (1957). *Proc. Tenth Annu. Mtg Southern Weed Conf.* 207

Pangola Grass (Digitaria decumbens *Stent) in the United States Virgin Islands*

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Vegetative material of Pangola grass (*Digitaria decumbens* Stent) was introduced into the United States by the Division of Plant Exploration and Introduction, United States Department of Agriculture, in 1935, from collections made in South Africa. Hereafter, Pangola grass will be referred to in this paper as Pangola.

Research workers in the south eastern United States spent several years in evaluating Pangola under different soil and climatic conditions (McCloud, 1953). This relatively new pasture grass became popular with cattlemen in a very short time, and was rapidly increased in acreage. Florida was growing half a million acres of it by 1955, and it had spread to the southern portions of the other States which border on the Gulf of Mexico. It was introduced into the Commonwealth of Puerto Rico and the United States Virgin Islands from the United States of America. The British Virgin Islands, i.e. Tortola, obtained planting material from this station in 1955. It occurs on other islands throughout the Caribbean as the senior author observed it growing in varying amounts on islands as far south as Trinidad in 1957.

AGRONOMIC CHARACTERISTICS

Pangola thrives well over a rather wide range of soil and rainfall conditions. It possesses several desirable characteristics to make it a superior pasture grass in the tropics at the lower elevations. Among these are its tolerance of a wide range in soil moisture, pH and fertility, its ease of establishment, drought tolerance, aggressiveness and competitiveness against weeds. It is also noteworthy for its ability to withstand and recover rapidly from overgrazing. It is among the most palatable grasses, to all classes of livestock, of those tested in the Virgin Islands.

Its habit of forming a dense mat or ground cover is probably a disadvantage in trying to grow it in combination with a legume, since it suppresses, under most conditions, herbaceous viny legumes which are commonly associated in varying degree with other tropical pasture grasses. But this same growth habit and competitiveness enhance its ability to keep out pasture weeds, thus materially reducing the cost of pasture maintenance. Its success in competing with noxious pasture pests appears to outweigh by far its unsuitability for a grass–legume combination.

Once established, Pangola is quite drought tolerant, much more so than Guinea grass (*Panicum maximum* Jacq.), St Augustine grass [*Stenotaphrum secundatum* (Walt.) Kuntze] or Molasses grass (*Melinis minutiflora* Beauv.). Its drought tolerance is perhaps comparable to that of Rhodes grass (*Chloris gayana* Kunth) or Buffel grass [*Pennisetum ciliare* (L.) Link], but it is much

more palatable than either. This drought tolerance of Pangola has not been fully explained. It does not seem to be caused by its rooting habits, since our data in *Table 1* show marked differences in distribution of the root systems of Pangola and the perhaps slightly less tolerant Coastal Bermuda grass [*Cynodon dactylon* (L.) Pers.] when grown on Fredensborg clay. This soil is underlaid with loose marl and soft limestone and has a comparatively poor water-holding capacity. Approximately three fourths of the roots of Pangola are in the top foot of soil with less than 10 per cent below 2 ft. Coastal Bermuda grass has a more even distribution of its roots to the 3 ft depth. Pangola does seem to have a higher proportion of very fine roots, in addition to having a greater weight of roots, thus perhaps providing more absorptive surface area than does Coastal Bermuda grass.

Pangola does not pose a serious threat of becoming a weed, as it can be eradicated by both herbicides (non-selective) and proper cultural practices, i.e. turning the sod to a shallow depth to expose the grass roots, followed by a disc harrow or other suitable tool to tear up the sod and remove the grass roots from the field. Such practices for eradication should be done in the dry season. Even though the roots of Pangola are relished by swine, it is not advisable to utilize them for eradicating the grass because of damage to soil tilth and texture. Soil sterilants will kill the grass, when used in sufficient quantities; but they have the disadvantage that their residual effects may render the soil sterile for various time intervals following their application.

Table 1. Dry weights (grammes) of roots taken at various depths of Pangola grass (Digitaria decumbens *Stent*) *and Coastal Bermuda grass* [Cynodon dactylon (*L.*) *Pers.*] *when grown on Fredensborg clay*

Depth in.	*Pangola grass*		*Coastal Bermuda grass*	
	Wt, g	*Per cent*	*Wt, g*	*Per cent*
0–6	107·4	61·30	27·9	26·45
7–12	22·5	12·84	17·6	16·68
13–24	28·1	16·04	29·8	28·25
25–36	11·3	6·45	23·9	22·65
37–48	5·9	3·37	6·3	5·97
Total	175·2	100·00	105·5	100·00

DISEASES AND PARASITES

The authors do not know of any diseases of Pangola. The most frequently reported insect damage to the grass is that caused by the sugar-cane aphid, *Sipha flava* Forbes. Farmers in various parts of Puerto Rico and the United States Virgin Islands have become alarmed from time to time by these aphid attacks. In most instances observed by the writers the attacks have occurred on old ungrazed or uncut grass. The few attacks observed on young grass were of very light intensity. It is suggested that aphid infestations, which may reach alarming proportions under certain circumstances on old unused grass, may be indicative of under-usage of the crop. Pangola, like other grasses, is subject to damage by various chewing insects, which can be minimized by timely applications of the common insecticides.

ESTABLISHMENT

Pangola produces copious seed heads during the winter months, but the seeds are not available due to the high degree of male sterility (SHETH *et al.*, 1956). For this reason Pangola must be propagated vegetatively. Vegetative reproduction, whether it be by runners or rootstocks, adds to the cost of establishment, especially when the cost of labour is high. Under most circumstances, however, the returns derived from a well-established stand of Pangola outweigh by far the cost of its establishment.

Pangola, of course, grows more rapidly and, consequently, covers more quickly when planted on a well-prepared seedbed, but given enough time it can be established almost without preparation. We cannot make any specific recommendations regarding the spacing in planting this grass, as that will be determined by the rapidity with which a ground cover is desired and the amount of propagating material available; 3 ft × 3 ft has generally given good results. Several planting methods have been used successfully. The choice of the method used would depend upon availability and cost of labour, acreage to be established, and soil type and slope. The steepness of the slope will determine whether or not mechanical equipment can be utilized in the planting process. Mechanical transplanters, like those usually employed in planting tobacco and vegetable crops, have been quite successful on relatively flat land. Several makes of these transplanting machines, which may plant one or more rows at once, are available throughout the United States, as well as other countries. Many of the machines are equipped with watering devices which may be used, when it becomes necessary, in the planting operation. Best results are obtained with mechanical transplanters when the land is in an excellent state of tilth. Land which is too wet and sticky will clog the machines, whereas large clods or crop residues incorporated at or near the surface will prevent firm planting.

Seedbed preparation may be either flat or ridged, the former being better for mechanical transplanters. Hand planting is done by furrowing about 6 in. deep or by digging holes, with a mattock, hoe, or other suitable tool, in which to plant the grass. Both runners and sprigs may be planted in this manner. Another method that has been successful is to cover ploughed land lightly with runners or cuttings (a manure spreader may be used), to be followed by a disc harrow. The harrow should be set at an angle so as partially to incorporate the grass runners into the soil without burying them too deeply. A seedbed roller or cultipacker may be pulled behind the harrow to firm the soil. This method of planting is comparatively cheap, especially for large areas, but better soil moisture conditions are needed than for the other methods.

For ridged seedbed preparation the furrows should not be too deep in order that the ridges may be flattened during the planting operation. The runners or rootstocks are placed in the bottom of the furrows and covered by a disc harrow or other suitable tool. A cultipacker may be effectively used in firming the soil following planting. From 0·5 to 1 ton of sprigs or runners is required to plant 1 acre, depending upon the spacing.

RESPONSE TO FERTILITY

Because Pangola is relatively new in this area its salient agronomic characteristics over the wide range of soil types and climatic conditions found throughout the Caribbean are yet to be determined. Several workers have conducted fertility experiments with it in the United States (Blaser *et al.*, 1945; Hodges *et al.*, 1951; Wallace *et al.*, 1957), and Jamaica (Anon., 1957). Fertility experiments have been carried out by the writers in an effort to determine: (*1*) its maximum yield and (*2*) the fertility level from which maximum returns may be derived. The soils of the United States Virgin Islands are significantly low in nitrogen, a condition common among tropical soils. In addition, most Virgin Islands soils are high in calcium and, consequently, high in pH. Clay soils predominate, there being comparatively few clay loams and practically no sandy loams. Fertilizer trials were located initially on Fredensborg clay, one of the better cane soils on St Croix. This soil is deep to moderately deep and is underlaid by a loose marl or soft limestone which reduces its water-holding capacity. The pH of this soil is approximately 8·5.

The fertilized plots received single, annual applications of fertilizer, 12–6–8 at 800 lb/acre as a top dressing. The initial fertilizer application was made on newly established sod. Statistically significant increases ($P=0{\cdot}05$) in yields were obtained only for the first two cuttings following each fertilizer application, showing that the fertilizer remaining in the soil by the third cutting was negligible. An increase in forage yield of approximately 50 per cent was obtained over a 2 year period from the fertilizer application. These findings are in agreement with those of Wallace *et al.* (1957), who found significant differences in Pangola yields as a result of changing the time sequence of nitrogen application and harvest date. They concluded that the superiority of certain time sequences in some years depended upon the rainfall distribution for the particular year. Our rainfall distribution pattern is so erratic that we have only two periods a year at which fertilizers may be applied with any reasonable assurance of success, i.e. September–December and April–May. In this first experiment the fertilizer was applied only during the autumn rainy season, and the grass was not irrigated.

Subsequently, another fertilizer experiment, a split plot design, with a series of treatments involving four rates of nitrogen and two application dates was established. Though this study has not yet been completed, it has already furnished valuable information. The grass was planted in the winter of 1955–56, received its initial application of fertilizer as a top dressing in July 1956, and was first harvested in August. Subsequent fertilizer applications were made in April and August 1957. The fertilizer treatments consist of: 0, 75, 150, and 300 lb of nitrogen per acre per year, in the form of ammonium sulphate, applied twice annually with about two thirds of the total being used in the autumn and the remaining third in the spring.

So far the crop has been harvested six times and the yield data are given in *Table 2*. All samples were dried in a forced air drier at 110° to 125°F, and yields are expressed as tons of dry material per acre. For individual harvests, increases in forage yields resulted for each additional increment of

nitrogen applied with one exception, that between treatments B and C for the third harvest. Statistically significant differences ($P=0.05$) were found between the cumulative yields for each treatment as was expected. In general, there is an increase in yield for each additional increment of nitrogen applied, though at the higher rates each added increment produced less forage. As shown in *Table 2*, 89 lb of dry matter was produced per pound of nitrogen for treatment B, whereas only 34 lb was produced by treatment D. The relationship between the cumulative yields of the different fertilizer treatments may be expressed as a ratio. Assuming the cumulative yield of treatment A (no fertilizer) to be 100, then the values of treatments B, C and D would be 146, 168 and 225, respectively.

Table 2. Yields (tons of dry matter per acre) for six harvests of Pangola grass (Digitaria decumbens *Stent*) *when grown at four fertility levels on Fredensborg clay*

Harvest	*Date*	*Treatment and added nitrogen, lb/acre* *A* 0	*B* 75	*C* 150	*D* 300
First	31 *Aug* 56	1·175	*2·217*	*3·057*	*3·732*
Second	3 *Dec* 56	*1·160*	*1·131*	*1·395*	1·915
Third	15 *Mar* 57	1·027	1·557	1·144	1·795
Fourth	30 *Jul* 57	0·144	0·228	0·520	0·752
Fifth	15 *Nov* 57	0·579	*0·835*	*1·094*	*1·148*
Sixth	28 *Jan* 58	2·775	*4·195*	*4·330*	6·110
Total		6·860	10·053	11·540	15·452
Ratio		100	146	168	225
Yield: lb dry matter/lb nitrogen applied			89	51	34

NOTE: LSR. Any two means not italicized are significantly different ($P=0.05$) (DUNCAN, 1955).

CARRYING CAPACITY

Since a pasture grass cannot be evaluated by its yields alone, experiments were conducted to determine both its carrying capacity and its beef-producing capacity when grown without fertilization on different soil types at different locations. Carrying capacity trials were established on Hope clay, Modified Hope clay, and San Anton loam. As Guinea grass is considered the 'bread-and-butter' grass throughout the Caribbean, and especially in the United States Virgin Islands, it was used as the check. Coastal Bermuda grass was also evaluated simultaneously with Pangola. The data for Pangola and Guinea grass obtained in these trials are given in *Table 3*. The considerably higher values reported from Jamaica and elsewhere we attribute largely to differences in the amount and distribution of rainfall. The performance ratio given in *Table 3* is arrived at by assigning the performance of the standard Guinea grass as 100. The contrast between the two grasses is most striking on San Anton loam, whereas they performed equally well on Hope clay under poorer moisture conditions. Pangola afforded more continuous grazing time than did Guinea grass on two of the three soil types tested, while there was no significant difference between the two grasses on the third, Hope clay.

Table 3. Carrying capacity of two tropical grasses when grown on three soils: San Anton loam, Hope clay, and Modified Hope clay

Location and soil type	*Species*	*Duration of grazing, months*	*Grazing rounds*	*A.U. * per acre/year*	*Ratio*
Cotton Valley	*Pangola*	24	12	1·93	156
San Anton loam	*Guinea grass*	26	14	1·24	100
La Grange	*Pangola*	16	7	1·23	113
Modified Hope clay	*Guinea grass*	15	7	1·09	100
Whim	*Pangola*	18	5	0·64	98
Hope clay	*Guinea grass*	18	6	0·65	100

*A.U. = Animal unit(s), equivalent to one grown cow.

COMPETITION WITH *Andropogon pertusus* (L.) Willd.

Coastal Bermuda grass, which was included in these trials with Pangola, was equal in performance to the latter with one notable difference. The Pangola was far superior to the Bermuda grass in its ability to compete with weeds. That Pangola exceeds many other tropical grasses in both aggressiveness and competitiveness was repeatedly demonstrated in various experiments. Of particular interest is one experiment in which an effort was made to replace an undesirable grass species.

A sod grass [*Andropogon pertusus* (L.) Willd.], locally called Hurricane grass, constitutes a major pasture pest throughout the United States Virgin Islands, particularly on the island of St Croix. A randomized block field test was designed using Pangola, Coastal Bermuda grass, and Guinea grass in an effort to replace this undesirable pasture grass with more desirable species. These grasses were planted in a well-established sod of Hurricane grass in which furrows had been made with a subsoiler at 3 ft intervals, leaving the sod between the furrows intact. All three grasses were established, at the onset of the rainy season, by using vegetative material. After the grasses had become established they were grazed as growth permitted in order to simulate the conditions under which the farmer would be operating. Complete stands were obtained for all three grasses during the initial growing season, but after four years growth both the Guinea grass and Coastal Bermuda grass had almost completely succumbed to grazing and the severe competition from Hurricane grass. On the contrary, the Pangola grew and spread over the intervening undisturbed sod between the furrows and formed a complete ground cover over the planted area within two years. Furthermore, it had encroached into all the surrounding plots to a considerable distance within four years, at which time the experiment was terminated. Each of the planted grasses was superior in palatability to the Hurricane grass, and was therefore at a disadvantage because of the effects of selective grazing.

Nevertheless, Pangola not only maintained and extended its stand throughout the experiment but did an excellent job of keeping down noxious pasture weeds. Its competition was better against herbaceous vines, such as *Ipomoea*, *Dolichos*, *Dolicholus*, *Meibomia*, *Galactia* and *Quamoclit*, than against woody weeds. These observations of Pangola behaviour with Hurricane grass are in contrast to those reported for its behaviour with

Venezuela grass (*Paspalum fasciculatum* Willd. Flugge; ANON., 1956) in Puerto Rico, where concern was expressed about the possibility of Venezuela grass crowding out Pangola.

BEEF PRODUCTION

Pangola was planted on Modified Hope clay to determine its beef producing capacity. Young heifers of the St Croix breed cattle were utilized as test animals. There was more variation in the gains of individual animals fed on Pangola than among those fed on Coastal Bermuda grass. Statistically significant differences in animal gains were found between the two grasses for the first two grazing rounds. The very small loss in weight of the animals on Pangola for the second grazing round is credited to the laxative effect of the extremely lush growth of the grass at that time. The grazing trials were carried out in paddocks of three acres each and are reported for 435 days. Each grass was grazed the same number of rounds within this period, and each afforded approximately the same number of grazing days throughout the duration of the trials. It should be noted that the grazing rounds were fairly well distributed and included the wet and dry seasons. Pangola was grazed a total of 97 days with an average of 12·8 animals per grazing round whereas Coastal Bermuda grass was grazed for 94 days with a mean of 13 animals. These trials were made in 1957, the second driest year on record for St Croix. The superiority of Pangola is shown by its producing statistically significantly higher gains during the critical dry March–April period and by its total yield per year (see *Table 4*).

Table 4. Mean gains in pounds per head per day of St Croix breed cattle when fed for 435 days on Pangola grass and Coastal Bermuda grass grown on Modified Hope clay

Grazing round	*Pangola grass*		*Coastal Bermuda grass*	
	No. days and dates grazed	*Gains*	*No. days and dates grazed*	*Gains*
First	(28) *Mar–Apr*	2·287	(28) *Mar–Apr*	0·243*
Second	(19) *Aug*	(—) 0·186	(9) *Jul–Aug*	0·062†
Third	(20) *Oct*	1·082	(20) *Sep–Oct*	0·598
Fourth	(10) *Dec–Jan*	1·267	(15) *Jan–Feb*	0·996
Fifth	(20) *May–Jun*	1·438	(22) *Jun–Jul*	1·552
Total gain/acre/year		430·4		327·1‡
Mean daily gain		1·171		0·871

*Significant $P = 0{\cdot}01$, $t = 7{\cdot}999$ †Significant $P = 0{\cdot}01$, $t = 6{\cdot}754$ ‡Significant $P = 0{\cdot}01$, $t = 3{\cdot}392$

SUMMARY

Pangola was introduced into the United States from South Africa in 1935. From the southern United States, where it quickly became an important pasture grass, it was introduced into the Caribbean.

It has been found to be adapted to a wide range of soil and climatic conditions. In the Virgin Islands it is grown successfully on clay soils of pH range from 6·5 to approximately 8·5 in belts of annual rainfall of from about 20 to 60 in.

Various methods of planting the grass are described. Pangola was found to be rather drought-tolerant, requiring only a moderate amount of soil

moisture to become established, and remaining green throughout the dry season. This is in contrast to Guinea grass, the standard forage grass of the Caribbean. The aggressiveness and competitiveness of Pangola exceeds those of Coastal Bermuda grass, Hurricane grass and Guinea grass as was demonstrated in field plantings. Its superior competitive ability is advantageous in keeping down pasture weeds but disadvantageous for use in a grass–legume combination. Its ability to withstand overgrazing and excessive trampling by livestock and still remain alive and recover rapidly, make Pangola outstanding among tropical pasture grasses.

Forage yield is increased by fertilizer, at least up to 300 lb of nitrogen per acre per year in split applications. Increased yields were obtained for each increment of nitrogen applied, though at the higher rates each increment produced less forage.

Evaluation of the carrying capacity and beef-producing ability of Pangola was made by field trials on three soil types at three locations. Its carrying capacity, as measured by the number of grown cattle it would sustain throughout the entire year, varied from 0·64 to 1·93 animals per acre depending primarily upon differences in soil type and rainfall.

Pangola was found to be more variable than Coastal Bermuda grass in beef production under the conditions of this experiment. Although the carrying capacity of the two grasses was identical the superiority of Pangola is demonstrated by its higher gains during critical dry periods and by its total yield per year.

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REFERENCES

Anon. (1956). ' Pangola grass does not resist competition from Venezuela grass. ' *Impex* **5**, (2), 6

Anon. (1957). ' Pasture experiments show subdividing is profitable. ' *J. Jamaica agric. Soc.* **61**, (6), 694–801

Blaser, R. E., Stokes, W. E., Warner, J. D., Ritchey, G. E. and Killinger, G. B. (1945). ' Pastures in Florida. ' *Univ. Fla agric. Exp. Sta. Bull. No. 409*

Duncan, D. B. (1955). ' Multiple range and multiple *F*-tests.' *Biometrics*, **11**, 1–42

Hodges, E. M., Jones, D. W. and Kirk, W. G. (1951). 'Grass pastures in Central Florida.' *Univ. Fla agric. Exp. Sta. Bull. No. 484*

McCloud, G. A. (1953). ' Symposium; breeding crop plants for better adaptability to Florida conditions. Forage and cover plant introduction by the Florida Agricultural Experiment Station.' *Soil Sci. Fla Proc.* **13**, 32–38

Sheth, A. A., Yu, Lillian and Edwardson, E. (1956). ' Sterility in Pangola grass (*Digitaria decumbens* Stent).' *Agron. J.* **48**, (11), 505–507

Wallace, A. T., Killinger, G. B., Bledsoe, R. W. and Duncan, D. B. (1957). ' Design, analysis and results of an experiment on response of Pangola grass and Pensacola Bahia grass to time, rate and source of nitrogen.' *Tech. Bull. No. 581.* Florida Agricultural Experiment Station, Gainesville, Florida

Investigations on a Seedling Die-back of Theobroma cacao *L. in Nigeria—I*

Description of the Disease and its Spread in the Nursery

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A seedling disease of cacao caused by *Phytophthora* sp. has already been briefly described (Chant, 1957). Although this disease was first observed in the Western Region of Nigeria in August 1954, it possibly occurred there and in other parts of West Africa before that date.

A similar seedling disease has been observed in Costa Rica (Orellana, 1952) and Suriname (van Suchtelen, 1955). However, it is common in those countries for leaves and chupons of the cacao tree to be attacked also by *Phytophthora*, whereas in West Africa, apart from the occurrence of the seedling disease, *Phytophthora* has not been recorded as affecting, under natural conditions, any part of the cacao plant other than the cushion and pod.

This paper gives more detail on the symptoms of the disease and describes its spread in the nursery.

EXTERNAL SYMPTOMS

Normally the first sign of the disease is a brown discoloration at the tip of one of the leaves of a young cacao seedling (*Figure 1*). This discoloration is followed by a blackening and wilting of the petiole and later the upper part of the stem. The necrosis then spreads down the stem as far as the cotyledons and at this stage there is usually a collapse of the upper part of the stem. The disease appears about four weeks after sowing and the seedlings appear to be highly susceptible till they are about six weeks old. Very few seedlings have been observed to become infected after they are eight weeks old.

If the necrosis does not proceed down the stem as far as the cotyledons the seedling may recover owing to the development of buds in the axils of the cotyledons (*Figure 2*). This type of recovery occurs amongst plants infected towards the end of their period of susceptibility, particularly if dry conditions prevail during the period immediately following infection.

Sporangia of *Phytophthora* sp. appear on the petiole and upper part of the stem five to six days after infection (*Figure 3*) although in a few instances they have been observed four days after infection. Cultures of this fungus have been provisionally identified at the Commonwealth Mycological Institute as *Phytophthora* sp. [near *P. palmivora* (Butl.) Butl.].

ANATOMY OF DISEASED TISSUES

Sections of petioles and stems of infected seedlings showed the presence of *Phytophthora* sporangia on the surface of the epidermis (*Figure 4*) and the

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Figure 1. Young cacao seedling showing necrosis of the midrib and petiole of a young leaf in the early stage of infection by Phytophthora *sp.*

Figure 2. Cacao seedlings which have recovered from die-back owing to development of buds in the cotyledon axils

Figure 3. Infected seedling showing production of sporangia of Phytophthora *sp. on the surface of the stem*

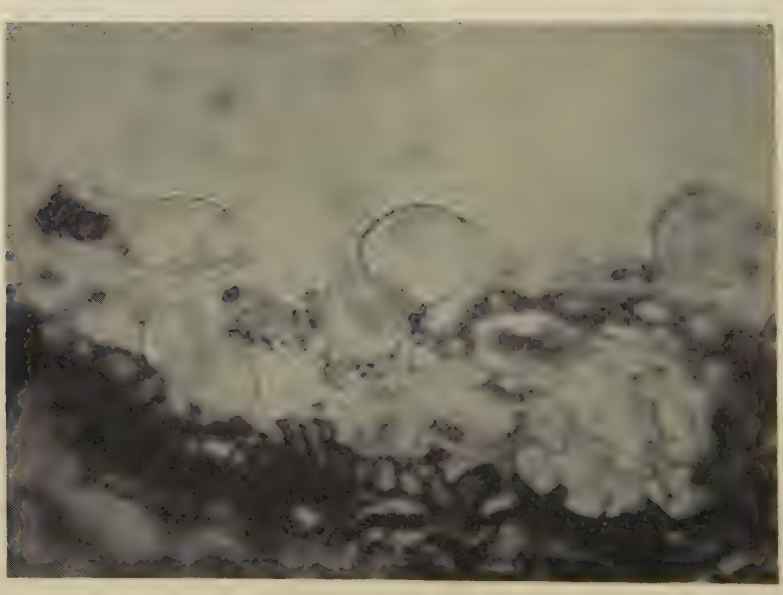

Figure 4. T.S. stem of infected cacao seedling showing production of sporangia of Phytophthora *sp. on the epidermis. Magnification: × 550; reduced ⅓ in reproduction*

sporangiophores developed from hyphae in the tissue of the epidermis and outer cortex. In the early stages of infection, hyphal growth is sparse and intracellular haustoria are found only in the epidermis and outer cortex but later there is a general invasion of the parenchymatous tissue of the cortex and pith. At this stage there is complete collapse of the stem. The xylem tissue in the vascular bundles does not appear to be invaded although in the later stages of infection it becomes deeply discoloured. The downward growth of hyphae in the stem is preceded by considerable deposition of dark-staining material in the epidermal and cortical cells.

SPREAD OF THE DISEASE

The occurrence and spread of the die-back was studied in four isolated plots (20 feet apart) each containing 200 potted seedlings in a cacao nursery. Four observations were made at four-day intervals from the date of the first appearance of the disease, the position in the plot of newly infected seedlings being noted on each date.

By means of VAN DER PLANK's method of analysis (1946) it was found that the number of pairs of adjacent infected seedlings often exceeded the numbers to be expected if the disease was distributed at random (*Table 1*).

Table 1. Incidence of pairs of adjacent diseased cacao seedlings in four plots (200 seedlings per plot)

Plot	*Date of observation*	*No. of diseased seedlings*	*No. of pairs*		*Difference (observed — expected)*	*Standard error ±*
			Observed	*Expected*		
1	24.9.58	4	0	0·06	— 0·06	0·24
	28.9.58	10	1	0·45	0·55	0·67
	2.10.58	48	29	11·48	17·52	3·39
	6.10.58	60	35	17·70	17·30	4·2
2	24.9.58	8	1	0·28	0·72	0·53
	28.9.58	30	6	4·35	1·65	2·09
	2.10.58	52	26	13·26	12·74	3·64
	6.10.58	58	29	16·53	12·47	4·07
3	24.9.58	4	0	0·06	— 0·06	0·24
	25.9.58	16	0	1·8	0·06	1·34
	2.10.58	34	8	5·61	2·39	2·37
	6.10.58	46	13	10·35	2·65	3·22
4	24.9.58	10	1	0·45	0·55	0·67
	28.9.58	32	5	4·96	0·04	2·23
	2.10.58	36	8	6·3	1·70	2·51
	6.10.58	58	15	16·53	— 1·53	4·06

However, between the numbers of observed and expected pairs in two of the plots, the differences were less than their respective standard errors. Therefore, in the early stages of the attack at least, infection probably occurs at random, although it appears possible that later infections depend on the loci of the first infected seedlings with resultant neighbour spread.

EXPERIMENTAL METHODS

Attempts to isolate *Phytophthora* by plating out small portions of stems on agar were not satisfactory. Even when the stems were surface-sterilized

with calcium hypochlorite or mercuric chloride the *Phytophthora* was almost invariably contaminated with bacteria and other fungi, e.g. *Aspergillus* sp. and *Fusarium equiseti* (Corda) Sacc., and could be isolated only with difficulty.

Pure cultures of *Phytophthora* were readily obtained by the following method. Small portions of infected stems, $\frac{1}{4}$ to $\frac{1}{2}$ in. in length, were washed under running tap water for 12 hours after which they were implanted in incisions made in egg plant (*Solanum melongena* L.) fruits and cacao pods, the surface of which had been sterilized with 95 per cent alcohol. The egg plant fruits and cacao pods were then placed on damp sterile blotting paper in sterilized jars. After 72 hours a large discoloured area was seen in the region of the inoculation. Portions of sub-epidermal tissue from this area were placed on potato dextrose agar in Petri dishes and after 48 hours the resultant colonies were sub-cultured and grown in tubes on corn meal agar in which had been incorporated thiamine (6 μg per 10 cm^3 of medium). The *Phytophthora* readily produced sporangia in culture and these were compared with isolates from naturally infected black pods from the field.

Inoculation experiments were carried out in the greenhouse on potted four-, eight- and 12-week old seedlings of Upper Amazon parentage. The inoculum was an aqueous suspension containing more than 10 000 sporangia per millilitre derived from the surface of cacao pods inoculated under sterile conditions, with the isolates of *Phytophthora* from wilted seedlings. Inoculation was either (*a*) by wounding the seedlings, i.e. cutting the epidermal tissue of a petiole a quarter of an inch from the leaf base, or stem half an inch below the apex, and injecting the sporangial suspension with a fine glass pipette, or (*b*) by spraying unwounded seedlings with the suspension of sporangia from an atomizer. Controls of wounded but un-inoculated seedlings and unwounded seedlings sprayed with water only were also set up and given the same subsequent treatments as the inoculated seedlings. The seedlings were watered heavily at two-day intervals after inoculation and half of them in each treatment were covered with polythene cages to maintain the relative humidity above 90 per cent.

RESULTS

Measurements of 100 sporangia from each of the two sources (pods and seedlings) corresponded almost exactly (*Table 2*).

Table 2. Mean values of length, diameter, and length/diameter ratio of Phytophthora *sporangia from cacao pods and cacao seedlings artificially inoculated*

Source	*No. of sporangia measured*	*Length* μ	*Diameter* μ	*Ratio*
Seedlings	100	32·2 (±4·2)	21·9 (±2·6)	1·5
Pods	100	33·9 (±4·7)	22·3 (±3·5)	1·5

Since it is considered that the sporangia are smaller than those usually described for *P. palmivora* (Butl.) Butl. the identification of the fungus has not yet been confirmed by the Commonwealth Mycological Institute.

In the inoculation experiment the relative humidity for the uncovered seedlings varied considerably with the prevailing weather conditions but

was usually lower than 90 per cent (except during the night and early morning) and averaged 74 per cent at mid-day for twelve days after inoculation. Temperature in the greenhouse did not fall below 76°C for the period. Results were assessed twelve days after inoculation (see *Table 3*).

Table 3. Number of cacao seedlings infected after wounding or spraying with a suspension of Phytophthora *sporangia*

Age of seedlings when inoculated, weeks	*Condition of leaves*	*Treatment subsequent to inoculation*	*Infected seedlings after wounding (10 per treatment)*		*Infected unwounded seedlings (10 per treatment)*
			Stem wound	*Petiole wound*	
4	*Semi-hardened, still expanding*	*Uncovered*	5	2	0
		Covered	7	4	5
8	*Hardened, almost fully expanded*	*Uncovered*	6	2	0
		Covered	6	3	0
12	*Hardened, fully expanded*	*Uncovered*	4	5	0
		Covered	2	1	0

None of the controls became infected.

Although a high percentage of infection was obtained in seedlings in all three age groups after wounding, only four-week old unwounded seedlings became infected.

DISCUSSION

From a study of the infection patterns in plots of seedlings it was observed that, in general, the later infected seedlings were found near the original infections. This indicates that spread is by air-borne rather than by soil-borne sporangia. It was proved experimentally that *Phytophthora palmivora* was present in the potting soil but it has also been established that soil sterilization (Chant and Hall, 1959) had no effect on the incidence of die-back. Thorold (1952) has demonstrated that dispersion gradients for sporangia occur over long (180 m) distances as well as over short (3 m) distances and, as there were considerable numbers of black pods on trees at a distance, of 60 m from the nursery sporangia from them probably caused the initial infections in the nursery. If, therefore, the early infections are due to air-borne sporangia coming from an outside source (i.e. from black pods) the distribution of infection on seedlings would tend to be random at great distances from the source. Under favourable conditions of temperature and humidity, *Phytophthora* sporangia appear on diseased stems five to six days after infection so that at this stage there would probably be a considerable amount of inoculum in the neighbourhood of such seedlings and the chances of infection of adjacent plants would be increased. This hypothesis receives some support from the fact that whereas the number of doublets was insignificant in the early stages of infection it increased greatly later, thereby indicating considerable spread from neighbour to neighbour.

The results from the inoculation experiments suggest that infection is greater when seedlings are maintained in very humid conditions. This appears to be particularly true when the seedlings have not been wounded before inoculation. It is of interest that of the unwounded seedlings with one exception only those in the four-week old age group became infected. GRAINGER (1956) has shown that the physiological ability of a potato plant to contract blight (caused by *Phytophthora infestans* Mont.) varies through its life cycle, there being an initial period of high disease potential and an intermediate stage of low potential followed by another high period. The changes in potential can be correlated with changes in the percentage of total carbohydrate in the potato plant, but it is not known whether this is so in cacao seedlings.

SUMMARY

The symptoms of a seedling die-back disease of cacao are described. Difficulty in obtaining pure culture of the causal agent [*Phytophthora* sp. near *P. palmivora* (Butl.) Butl.] from infected plants was overcome by inoculating cacao pods and egg-plant fruits with portions of infected stems. Inoculation experiments confirmed the observation that only young seedlings, less than eight weeks old, are susceptible to infection. Humid conditions are apparently a pre-disposing factor for the disease.

The disease appears in the first instance to occur at random in the nursery but subsequent spread is apparently from infected to adjacent plants.

ACKNOWLEDGEMENTS

This paper is published by permission of the Director, Department of Agricultural Research, Nigeria. I wish to acknowledge with thanks the assistance given in the nursery work by Mr T. R. Hall and Mr I. Ogunkua of the Western Region Department of Agriculture, Nigeria. I am indebted to Dr J. Robinson for helpful advice in preparing the manuscript.

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REFERENCES

CHANT, S. R. (1957). 'A die-back of cacao seedlings in Nigeria caused by a species of *Phytophthora*'. *Nature, Lond.* **180**, 1494

CHANT, S. R. and HALL, T. H. R. (1959). 'Investigations on a seedling die-back of *Theobroma cacao* L. in Nigeria—II. Factors affecting the incidence of the disease and its control'. *Trop. Agriculture, Trin.* **36**, 145

GRAINGER, J. (1956). 'Host nutrition and attack by fungal parasites'. *Phytopathology* **48**, 445

ORELLANA, R. C. (1952). *Tenth Annual Report* of the Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica for the year 1952. 160 pp

THOROLD, C. A. (1952). 'Airborne dispersal of *Phytophthora palmivora* causing black pod disease of *Theobroma cacao*'. *Nature, Lond.* **170**, 718

VAN DER PLANK, J. E. (1946). 'A method for estimating the number of random groups of adjacent diseased plants in a homogeneous field'. *Trans. Roy. Soc. S. Afr.* Ser. 8, **31**, 3 and 260

VAN SUCHTELEN, N. J. (1955). 'Top die-back of cacao in the nursery'. *Surinaam Landb.* **3**, 3 and 223

Investigations on a Seedling Die-back of Theobroma cacao *L. in Nigeria—II*

Factors affecting the Incidence of the Disease and its Control

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The symptoms of cacao seedling die-back caused by *Phytophthora* sp. have already been described (Chant, 1957, 1959) and it was suggested that some correlation existed between high humidity and high incidence of disease. Thorold (1955) has shown a relationship in Nigeria between relative humidity, rainfall and black pod infection caused by *Phytophthora palmivora* (Butl.) Butl. Under Nigerian conditions black pod infection usually reaches its maximum in September and October, and these have been the months during which most of the die-back of cacao seedlings has been observed.

Die-back disease caused considerable losses in the Western Region of Nigeria cacao nurseries in 1954 and the two years following and much attention was paid to both cultural and chemical methods of control. This paper describes the effect of environmental factors on the incidence of cacao seedling die-back and outlines the methods for its control.

EXPERIMENTAL METHODS AND RESULTS

Factorial experiments were laid down in 1955 and 1956 in the cacao nursery at Moor Plantation, Ibadan. Seeds were sown in ' whale hide ' pots (made of bitumenized paper pulp), the standard method employed by the Western Region Department of Agriculture.

Data were reduced to percentages (and summarized as such in the tables) but were transformed to angles for statistical analysis (Goulden, 1952).

Effect of shade, watering, spacing and soil type

Two fully randomized factorial experiments, one under light shade of oil palm fronds† and the other under heavy shade‡, were carried out in September 1955 to assess the effect of shade, watering, spacing and soil type on the incidence of disease in cacao seedlings derived from unselected Amelonado parents. The watering treatments were either heavy (1·5 gall per day per plot of 48 seedlings) or light (0·25 gall per day per plot of 48 seedlings) and the spacing was either close, i.e. the pots touching each other, or wide, i.e. 9 in. between pots. The soils used were a mixture

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†At noon in full sunlight the reading on the Weston light meter = 25 f.c.
‡At noon in full sunlight the reading on the Weston light meter = 3·2 f.c.

Table 1. Percentage incidence of die-back in cacao seedlings grown in different soil types under varying conditions of watering, spacing and shade (mean of 4 plots of 48 seedlings)

Watering	Spacing	Light shade		Heavy shade	
		Clay and compost soil	Sandy soil	Clay and compost soil	Sandy soil
Heavy	Close	5·5	0	14·5	0
	Wide	2·5	0	24·5	0
Light	Close	1·0	0	26·5	0·5
	Wide	1·0	0	19·0	0·5

In transformed data S.E. of a single plot = 4·2 and coefficient of variation for the experiment = 28·6 per cent.

of clay and compost (normally used in the nursery) or very sandy, quick-draining soil. The results are given in *Table 1.*

The incidence of die-back under light shade was so slight that statistical analysis was impracticable. Analysis of the transformed data from the experiment under heavy shade showed that the incidence of die-back in seedlings grown in the clay and compost soil was significant. Any effect of the watering treatments was concealed by heavy rainfall during the period from germination to disease assessment so that the seedlings grown in the clay and compost soil were waterlogged for long periods even when given the light watering treatment.

Effect of source of seed, seed treatment and soil sterilization

Another randomized factorial experiment was carried out in October 1956 to assess the effect of source of seed [i.e. from healthy pods or pods infected with *P. palmivora* (Butl.) Butl.], seed treatment, and soil sterilization on incidence of disease in Amazon seedlings.

Seed treatment consisted of dusting seeds with 'Agrosan GN' (an organic mercurial compound) in the ratio of two parts by weight of dust to 100 parts by weight of seed. The soil was sterilized by heating in a 40-gallon oil drum over an open fire. None of these treatments was found to give any control over the disease. Similarly the incidence of die-back in seedlings from healthy pods was not significantly different from that in seedlings from black pods.

Effect of variety and age of seedlings

To study the effect of variety and age of seedlings an experiment was laid down in July and again in September 1956, consisting of 600 pots (in blocks of 100) sown with Amelonado seeds and the same number sown with Amazon seeds, and the number of seedlings affected by die-back was noted every four days.

The disease which appeared in the September experiment only did so 24 days after planting and in both varieties the number of new infections reached a maximum 32 days after planting although the incidence of die-back was slightly greater in the Amazon seedlings. Both varieties tended to become less susceptible 36 days after planting and no new infections were recorded 44 days after planting.

Effect of relative humidity

Daily records of wet and dry bulb temperatures at 8 a.m. and 2 p.m. were kept in the nursery in 1956 to observe the effect of relative humidity on disease incidence. The means of the recordings over two periods (which coincided with the laying down of the two replications of the experiment) were as follows:

	4 July to 17 August	1 September to 14 October
8 a.m.	96	96
2 p.m.	84	92

During the first period the relative humidity at 2 p.m. exceeded 90 per cent on three days only whereas during the second period no reading was less than 90 per cent.

Control of the disease

Trials were carried out in September and October 1956 with the object of finding the most economical concentration at which ' Perenox ' could be used to control the disease, the frequency at which the fungicide should be applied, and the period of time over which spraying should be continued.

Seeds were sown in ' whale hide ' pots and after germination were watered heavily at the rate of 2 gallons per 100 seedlings per day. The seedlings were placed under heavy shade to induce die-back. ' Perenox ' was applied from a knapsack sprayer at the rate of 0·5 gallon per 10 seedlings.

An experiment was designed in September 1956 to assess the effect of ' Perenox ' applied at 0·1, 0·3 and 0·5 per cent concentrations at intervals of 3, 6, 9 or 12 days. A count of infected seedlings was made six weeks after sowing by which time no new infections were observed. The results are given in *Table 2.*

Table 2. Effect of ' Perenox ' applied from 1 week after germination at varying concentrations and time intervals, on the incidence of cacao seedling wilt (mean number of diseased seedlings in 4 plots of 100 seedlings)

Time interval between applications, days	*Concentration of fungicides*			*Control*
	0·1 per cent	*0·3 per cent*	*0·5 per cent*	
3	1·5	0·0	0·0	22·1
6	1·3	1·0	0·2	23·3
9	3·0	1·0	1·0	21·0
12	8·3	2·0	0·5	20·6

L.S.D. ($P=0·05$) = 2·8.

It is apparent that all the concentrations of spray used were effective in reducing the incidence of cacao seedling die-back. The 0·3 per cent spray was better than the 0·1 per cent but no greater control was obtained by increasing the concentration to 0·5 per cent. Spraying at 3- or 6-day intervals gave better control than spraying at 9- or 12-day intervals.

The effect of discontinuing spraying at three dates after sowing was also investigated. One hundred Amazon seeds per plot were sown in a randomized factorial experiment on 2 September and applications of 0·5 per cent ' Perenox ' were begun on 16 September. Spraying was continued

till 24 days after this date with various time intervals between applications. Die-back was assessed on 12 October and it was found that even when spraying was discontinued only 24 days after planting the control was still effective. Analysis of the data showed that spraying up to 31 or 38 days after sowing was more effective in reducing disease incidence than spraying only to 24 days.

DISCUSSION AND CONCLUSIONS

Of the pre-disposing conditions required for infection, the results show that heavy shade and high humidity are essential factors for the development of the disease. Under heavy shade the humidity is higher than under light shade, but the greater susceptibility of seedlings under heavy shade may be due to delay in ' hardening ' of the leaves and stem. VAN SUCHTELEN (1955) states that infection is obtained only on very young leaves and the tip of the plant dies back only as far as the old wood; this has been substantiated by the inoculation tests carried out in Nigeria (CHANT, 1959).

The greater incidence of disease in seedlings grown in a clay and compost soil is probably due to this soil being less permeable than the sandy soil and therefore becoming waterlogged. Under such conditions the cacao seedlings would possibly be more susceptible to attack by the *Phytophthora*. Further experimentation is required to confirm this.

The results of the ' Perenox ' spraying experiments show that it is necessary to spray seedlings at 3- or 6-day intervals from about three weeks after sowing till they are about six weeks old. The frequency of applications is probably necessary because of the fast rate of growth of the seedling and the production of new vulnerable tissue. There is little additional control obtained by increasing the concentration from 0·3 to 0·5 per cent so that 0·3 or 0·4 per cent spray is recommended as the standard concentration for Departmental nurseries. As the disease has not been observed before mid-August nor after the end of November in any of the past three seasons, it should be necessary to spray during the intervening period only. It is quite probable that other fungicides (e.g. Carbide Bordeaux) incorporating wetting agents would be as effective as ' Perenox ' and further trials are to be undertaken to compare their efficiency with that of ' Perenox '.

SUMMARY

A relationship is demonstrated between heavy shade and high relative humidity and the incidence of cacao seedling die-back disease caused by *Phytophthora* sp. This relationship appears to be similar to that already established between high rainfall and high relative humidity and the incidence of black pod disease. The incidence of die-back was greater in a heavy soil than in a sandy soil and this is presumed to be due to the waterlogging in the former under high rainfall. Such conditions might retard the growth rate of the seedling making it more susceptible to attack by the fungus. Soil sterilization and seed dressing had no effect on the subsequent incidence of die-back.

Applications of ' Perenox ' spray at 0·3 and 0·5 per cent at 3- or 6-day intervals from three weeks after sowing controlled the disease.

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REFERENCES

CHANT, S. R. (1957). 'A die-back of cacao seedlings in Nigeria caused by a species of *Phytophthora*'. *Nature, Lond.* **180,** 1494

CHANT, S. R. (1959). 'Investigations on a seedling die-back of *Theobroma cacao* L. in Nigeria—I. Description of the disease and its spread in the nursery'. *Trop. Agriculture, Trin.* **36,** 138

GOULDEN, C. H. (1952). *Methods of Statistical Analysis,* 2nd ed., p 92. Wiley, New York

THOROLD, C. A. (1955). 'Observations on black pod disease (*Phytophthora palmivora*) of cacao in Nigeria'. *Trans. Brit. mycol. Soc.* **38,** (4), 435

VAN SUCHTELEN, N. J. (1955). 'Top die-back of cacao in the nursery'. *Surinaam Landb.* **3,** 3 and 223

Control of Flowering in Indigofera endecaphylla *by Photoperiod Regulation**

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The lush growth of the giant grasses such as Napier grass (*Pennisetum purpureum* Schum.) and Guinea grass (*Panicum maximum* Jacq.) give forage production in the tropics a first appearance of opulence. However, it is known that the present forage resources of the tropics are deficient in quality since there are few recognized tropical forage legumes.

The legume, creeping indigo (*Indigofera endecaphylla* Jacq.) has attributes which tend to make it a very desirable forage plant. From the standpoint of quantity and, as measured by protein content, quality, it is a high producing plant (Paul, 1949; Stevenson, 1949; Guyadeen, 1951; Younge *et al.*, 1951; Warmke, Freyre and Garcia, 1952; Motta, 1953; British Guiana, 1950 a and b; Jamaica, 1951; Madras, 1952; C.S.I.R.O., 1955). Not only does it produce well in pure culture, but it is compatible with the giant grasses (Warmke, Freyre and Garcia, 1952; Motta, 1953; Payne and Naidu, 1955). Its leafiness and habit of rooting at the nodes of the stems which are in contact with the soil give it great powers of soil protection (Davis and Fiol-Villalobos, 1940; Paul, 1949; Gandhi, 1957). When it is remembered that some areas of the tropics are subject to torrential rains, the soil-protecting properties of this plant are seen to be particularly valuable.

Creeping indigo is also extremely palatable (Bogdan, 1949; Kenya, 1950). Warmke, Freyre and Morris (1952) report that in one test creeping indigo constituted only 10 per cent of the pasture area but provided 39 per cent of the grazing time. It is widely adapted to the tropics as indicated by the diverse geographical origins of the reports herein cited. Payne and Naidu (1955) state that it grows well in the wet zone of Fiji and is also drought-resistant.

These good properties of the plant are offset by the fact that it contains a chemical which under certain conditions produces toxicity (Emmel and Ritchey, 1941; Nordfeldt and Younge, 1949; Nordfeldt *et al.*, 1952).

Because of the desirable features of creeping indigo, it has been an object of research at the Hawaii Agricultural Experiment Station. Effort is being directed toward the production of a toxic-free strain. This programme would be facilitated if flowering could be controlled. In Hawaii, the species flowers most profusely in the winter. The object of these experiments was to determine whether, by artificial means, flowering could be initiated at any desired time of the year.

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As the literature on physiological control of flowering is voluminous and has been reviewed from time to time, mention need only be made of a recent review by LIVERMAN (1955). No published studies on the control of flowering in *I. endecaphylla* were found.

MATERIAL AND METHODS

All work reported in detail was with open-pollinated seedlings of clone 137, a selection of an introduction from the University of Puerto Rico. Other unrelated lines were also studied.

Experiments in Honolulu

Control of daylength was accomplished by moving the plants on carts from outdoors into light-tight chambers. These chambers have been described by NAKATA (1949 and 1952). Artificial light, controlled by time switches, was supplied in each chamber by fluorescent lamps giving an illumination of approximately 30 f.c. at the level of the plant. The work was done in the spring and summer when flowering of this species is at a minimum. The extended day was 21 hours in length and the short day was 10 hours.

A typical experiment is reported in detail. Seedlings were germinated under long-day conditions and continued therein until time of treatment which was 88 days after seeding. Examination at this time revealed no flower buds.

Five treatments consisting of 2, 4, 6, 8 and 10 cycles of short day were arranged by moving 25 plants (five for each treatment) into an adjoining light-tight chamber. They were then returned by groups of five on alternate days to the long-day régime and observations made on appearance of floral buds. The controls consisted of seven plants left under long day.

Experiments in Davis, California

These tests were conducted in the greenhouse during the winter. Long-day conditions were obtained by supplementing natural daylight with light from a bank of incandescent lamps about 30 in. above the plants to give a duration of 18 hours. Short-day treatments consisted of retaining the plants under the natural short daylength of the season, which was 9 hr 55 min. at the beginning of treatment. Treatment T_1 consisted of continuous short-day while T_2 was an exposure to 10 cycles of short day followed by return to long day. Control plants remained continuously under long day. The natural daylength had reached 10 hr 14 min. at the end of short day treatment for the T_2 lot, and 11 hr 52 min. at the end of the experiments (U.S. Naval Observatory, 1945).

Seedlings were grown under long-day conditions until treatments commenced. Growth of the plants at Davis was considerably less than anticipated from experience with their growth under Hawaiian conditions. Ninety one days after seeding the plants were sorted according to apparent physiological maturity, and grouped into 14 groups of three plants each. Individual plants were numbered, with the lower numbers in all cases being assigned to the less mature plants. This enabled detection of differences which might be associated with plant maturity. The plants were checked frequently for visible floral initiation.

RESULTS AND DISCUSSION

The results of the several cycles of short day on flowering are presented in *Figure 1*. Fourteen days after commencing short-day treatments, all but the four short-day cycle plants had commenced to flower or to show buds. Ten days later the behaviour showed greater significance. All plants in treatments with six or more cycles of short day exhibited buds or flowers; even those with two and four cycles showed more than 50 per cent of the plants flowering. The controls still had no visible buds. With more time several of the controls started to flower. At 27 days one control plant exhibited a flower bud, while at 34 days five of the seven controls came into bud or flower. The appearance of the young inflorescence is shown in *Figure 2*.

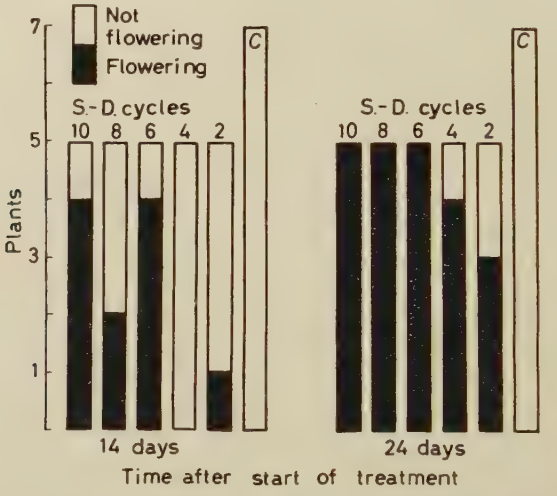

Figure 1. Effect of different cycles (2 to 10) of short-day treatment on floral induction in Indigofera endecaphylla *compared to plants kept under continuous long day (C). Readings at 14 and 24 days after beginning of short-day treatment. Experiments conducted at Honolulu, Hawaii*

Figure 3 illustrates the results of the experiments at Davis. Twenty one days after treatments commenced, nine of the 14 plants under continuous short day showed floral initiation. Only four of those treated with 10 short-day cycles exhibited any buds. The controls showed none. After 26 days all plants under continuous short day had begun to flower. Five plants treated with short day and returned to long day were also flowering. By this time two plants of the control group were showing flower buds. At 50 days half of both the control group and those receiving 10 short-day cycles had buds or flowers. Stage of maturity appeared to exert an influence since the majority of the plants which did not flower were those classified as least mature.

Because of the known effect of temperature on flowering in many plants, a record of the daily maxima and minima at the two locations is given for the period of daylength treatments (*Figure 4*). Davis showed more variability and greater extremes of temperature than Honolulu.

Figure 2. Young inflorescence of Indigofera endecaphylla *appearing after short-day treatment. Comparable plants under long-day régime showed no flower buds* (× ca. *1*)

In all experiments flowering was accelerated by short-day treatment. These results indicate that *I. endecaphylla* is a short-day plant as defined by LANG (1952). In preliminary experiments, a quantitative difference in tendency to flower was noted in plants of different genetic constitutions. The treatments which gave the largest number of flowering plants also gave the largest number of flowers per plant. This is of importance to those engaged in a breeding programme.

The results also emphasize the importance of physiological maturity. The mature plant may eventually flower in the absence of short days, while immature plants will not flower even if subjected to favourable photoperiod. The discrepancy between the ten cycle, short-day treatment at Honolulu and at Davis can be accounted for on this basis.

The natural flowering of *I. endecaphylla* in Hawaii in the winter might be construed either as a photoperiodic effect or a temperature response. Both factors may be involved. Since flowering did occur in Honolulu during the warmest part of the year after short-day treatment, however, it does not appear that temperature is critical in this response. Likewise, under the

higher temperature maxima at Davis, the controls came into flower at about the same rate as in Honolulu.

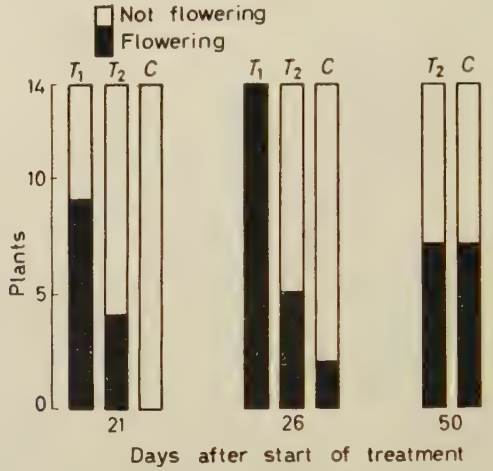

Figure 3. Effect of continuous short-day (T_1), 10 cycles short-day (T_2) and continuous long-day (C) on floral initiation in Indigofera endecaphylla. *Readings at 21, 26 and 50 days after beginning of treatment. Experiments conducted at Davis, California*

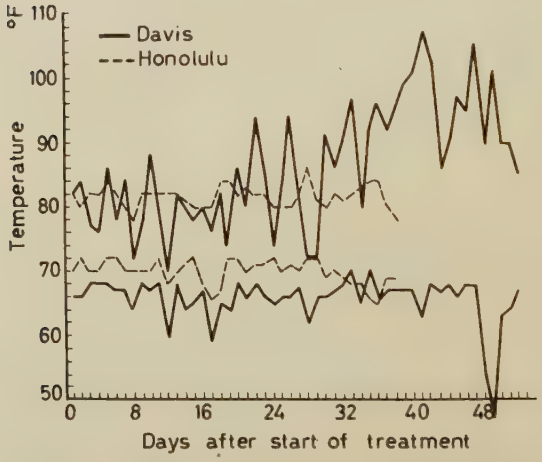

Figure 4. Maximum and minimum temperatures in the greenhouse at Davis, California and outdoors in Honolulu, Hawaii from the beginning of treatment with short days to the end of the experiment

SUMMARY

Experiments with *Indigofera endecaphylla* at Honolulu, Hawaii and Davis, California demonstrate that this species possesses short-day photoperiodic behaviour. Flowering is enhanced by advanced physiological maturity and may be prevented by immaturity. Temperature, at least within the moderate range of these experiments, does not appear to affect flowering.

The ability to control flowering will assist the geneticist in breeding programmes with this species.

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REFERENCES

Bogdan, A. V. (1949). 'Observations on palatability of some leguminous plants in Kenya.' *E. Afr. agric. J.* **15,** 38–40

British Guiana. (1950a). Administration *Report* of the Director of Agriculture for the year 1948

British Guiana. (1950b). Administration *Report* of the Director of Agriculture for the year 1949

C.S.I.R.O. Annu. Rep. 1955, p 36. Commonwealth Scientific and Industrial Research Organization, Australia

Davis, R. L. and Fiol-Villalobos, B. (1940). 'Trailing indigo, a promising leguminous forage plant.' *Soil Conserv.* **6,** 29–30

Emmel, M. W. and Ritchey, G. E. (1941). 'The toxicity of *Indigofera endecaphylla* Jacq. for rabbits.' *J. Amer. Soc. Agron.* **33,** 675–677

Gandhi, R. T. (1957). 'Plants suitable for soil conservation.' *Indian J. agric. Res.* **27,** 131–135

Guyadeen, K. D. (1951). 'A note on some promising tropical legume forages.' *Trop. Agriculture, Trin.* **28,** 231–232

Jamaica. (1951). *Rep. Dep. Sci. Agric. Jamaica*, p 18

Kenya. (1950). *Rep. Dep. Agric. Kenya, 1948*, p 162

Lang, A. (1952). 'Physiology of flowering.' *Annu. Rev. Pl. Physiol.* **3,** 265–306

Liverman, J. L. (1955). 'The physiology of flowering.' *Annu. Rev. Pl. Physiol.* **6,** 177–210

Madras. (1952). Administration *Reports* of subordinate officers of the Department of Agriculture, Madras, for 1950–51. (Original not seen)

Motta, M. S. (1953). '*Panicum maximum*.' *Emp. J. exp. Agric.* **21,** 33–41

Nakata, Shigeru. (1949). 'Photoperiodic response of *Lespedeza* spp.' *Master's Thesis*, University of Hawaii

Nakata, Shigeru. (1952). 'Photoperiodic response of *Lespedeza*.' *Plant Physiol.* **27,** 644–647

Nordfeldt, S. and Younge, O. R. (1949). 'Toxicity of creeping indigo to livestock.' *Progr. Note Hawaii Univ. agric. Exp. Sta. No. 55*

Nordfeldt, S. *et al.* (1952). 'Feeding tests with *Indigofera endecaphylla* Jacq. (creeping indigo) and some observations on its poisonous effects on domestic animals.' *Tech. Bull. Univ. Hawaii agric. Exp. Sta. No. 15*

Paul, W. R. C. (1949). 'On the value of some legumes.' *Trop. Agriculturist*, **105,** 109–116

Payne, W. J. A. and Naidu, R. K. (1955). 'The toxicity of creeping indigo (*Indigofera endecaphylla*).' *Agric. J. Fiji*, **26,** 1–3

Stevenson, G. C. (1949). 'Notes on the grazing lands of British Guiana.' *Trop. Agriculture, Trin.* **26,** 103–106

U.S. Naval Observatory. (1945). Nautical Almanac Office, Washington, D.C. *Tables of Sunrise, Sunset and Twilight* Suppl. to *Amer. Ephem.* (1946)

Warmke, H. E., Freyre, R. H. and Garcia, J. (1952). 'Evaluation of some tropical grass–legume associations.' *Trop. Agriculture, Trin.* **29,** 115–121

Warmke, H. E., Freyre, R. H. and Morris, M. P. (1952). 'Studies on palatability of some tropical legumes.' *Agron. J.* **44,** 517–520

Younge, O. R., Ripperton, J. C. and Takahashi, M. (1951). 'Creeping indigo investigations.' *Bienn. Rep. Hawaii Univ. agric. Exp. Sta.* (1948–50)

Book Reviews

AN INTRODUCTION TO TROPICAL AGRICULTURE

Sir H. Tempany and D. H. Grist. Longmans Green: London, 1958. *xvi*+347 *pp.* (illus.) 40*s*

In this book Mr Grist has revised and completed a text which the late Sir Harold Tempany had left unfinished at his death. The contents are in three parts: the tropical background, agricultural practice in the tropics, and economic considerations. As a survey of conditions and problems the scope is very wide, but no attempt is made to include practical instructions for the production of particular commodities.

In view of the distinguished experience of both authors, the book can only be described as disappointing. The treatment of most topics is superficial and uninformative, and there are many instances where the modern scientific approach to the subject is ignored. The lengthy list of references fails to include much recent scientific work of first-class importance. While the reader with absolutely no knowledge of the tropics will undoubtedly glean a good deal of information about them, this book cannot be recommended as representing informed current opinion among agricultural scientists or economists to those who are starting on a serious study of tropical agriculture.

The chapter on Tropical Soils contributed by Dr H. Greene is in a different category. This is a scholarly and indeed brilliant conflation of modern theories on the formation and classification of these soils. But it seems to be written for a different class of reader from the rest of the book, in pedological terminology at a level which is likely to be little understood by those whose main concern is with growing profitable crops on tropical soils.—G.B.M.

RICE IN INDIA

Compiled by R. L. M. Ghose, M. B. Ghatge and V. Subrahmanyan. Indian Council of Agricultural Research: New Delhi, 1956. *x*+507 *pp.* (illus.) *Rs* 21

This lengthy book is divided into three parts headed: 'Agriculture', 'Marketing' and 'Technology' respectively.

Part I, 'Agriculture', is much longer than the other two and is subdivided into three sections. The first of these gives a general description of the history and methods of rice cultivation in various localities in India. Details are also given of the main soil types on which the crop is grown, the irrigation and drainage methods used, and the water requirements of the crop. The more important diseases and pests of the different regions are briefly described. In the second section, after a brief introduction outlining the history of the various research centres, accounts are given of rice breeding work in India and the research programmes on agronomy and diseases and pests which are currently in hand. The third section of Part I describes

activities in the field of extension, and it is followed by five appendices. In these latter much of the information found in Section I is summarized in tabular form and lists are given of the fungi and other pests of rice found in India, together with information on improved rice strains and lists of plants used as green manures.

As the title of Part II implies, it is concerned with the post-harvest handling of rice in India, and a full account of this phase is given under ten headings which include among others, ' Supply ', ' Utilization and Demand ', ' Preparation for the Market ' and ' Classification, Grading and Standardization '.

Part III is the shortest, and deals with the processing of rice and the nutritive value of rice and rice diets. Techniques of milling and parboiling, which are little more than mentioned in Part II, are here discussed in fair detail, and the relationship between processing and the subsequent nutritive value of the product is clearly brought out.

The outstanding feature of this book is the incredibly large amount of information about rice production in India which has been collected between two covers, and for this reason alone it would deserve a place upon the bookshelf of anyone truly interested in rice. Like most books which attempt to cover a very wide field, certain subjects are dealt with rather better than others. The chapters on pests and diseases tend to be inadequate and would have been considerably improved by the provision of a number of illustrations similar to those used in other parts of the book, notably in the section entitled ' Genetics '. The description of the machinery used in rice milling is also rather too sketchy and again would have been improved by the addition of illustrations.

Based on information supplied by a large number of experts in various fields, this book is virtually a reference text, made the more valuable by the bibliographies at the end of Part I and in the section on Technology. Part I contains no less than 62 tables, a large number of lists which have not been numbered, and the five large appendices to which reference has already been made, and a further 34 tables are located in Part II. Most unfortunately, however, there is no index, and in a volume containing such a mass of information and covering such a wide field, this is a most serious omission which it is to be hoped that the editor M. G. Kamath and the publishers will rectify in any subsequent editions of this valuable book.—P.H.R.

HANUNÓO AGRICULTURE

A report on an integral system of shifting cultivation in the Philippines

H. C. Conklin. *F.A.O. Forestry Development Paper No. 12.* (Vol. II of the F.A.O. series on Shifting Cultivation.) F.A.O.: Rome, 1957. *xii* + 109 *pp.* (illus.) 10*s* or $2.00

This report is essentially a case study of a small section of a group of peoples in an upland area in southeast Mindoro island. It is a valuable report for two reasons; first it is a factual model of how such a community should be studied and secondly it emphasizes the point, brought out in Volume I, that shifting cultivation on a world basis is of many types and

that remedial measures where necessary should be applied only after local survey.

The author, Assistant Professor of Anthropology at Columbia University, carried out his field work in 1952–54 following many postwar years of experience in Malaysia during which he developed a strong interest in ecology. Thus he is well qualified to study the lives of primitive people so closely linked to the natural environment.

An introductory section deals briefly with general principles of shifting cultivation, in which ' firing and fallowing ' are seen to be common to all types, and suggests the use of an old English word *swidden* (lit. ' burned clearing ') to distinguish it from nomadic and other unplanned systems of migratory agriculture. *Swidden* farming is further subdivided into Partial systems, in which the cultivator is motivated by personal economic interests (such as resettlement, additional cash cropping) and the Integral system based on traditional, community ritual-sanctioned motives. A realization of these two basic divisions is necessary before a correct interpretation of their differing practices, as for example the tendency to mono-cropping in the former, may be made.

After a short but adequate description of the social organization of the people themselves the inorganic factors (climatic and edaphic) and organic factors (biotic) are briefly outlined. The inclusion of no less than 57 detailed soil analyses, chemical and mechanical, contrasts somewhat with very meagre rainfall data.

The main section of the report, prefaced by an interesting description of the food habits of the Hanunóo, deals in great detail with the agriculture of the *swidden* cycle which is fully described in terms of five phases: site selection, cutting, burning, cropping and fallowing.

Dr Conklin has used his specialized knowledge and experience to good effect and has produced a wealth of fascinating and valuable facts presented in logical and readily followed sequence. He has shown and analysed with microscopic inspection the complexities of what, to the casual, quick-touring visitor to many inhabited hilly areas of southeast Asia, appears to be a simple rather indolent system of agriculture. The book is well printed and contains 42 photographs of high descriptive standard. It will be of considerable value to both administrators and agriculturalists concerned with the well-being of primitive peoples in hill areas of the humid tropics in general and, owing to the wealth of botanical detail, to Philippine conditions in particular.—R.H.F.

THE AUGER-HOLE METHOD

A field measurement of the hydraulic conductivity of soil below the watertable

W. F. J. van Beers. (*Bulletin 1.*) International Institute for Land Reclamation and Improvement: Wageningen, 1958. 32 *pp.* (illus.) 4*s* 3*d*

Although the usefulness of the empirical technique described in this *Bulletin* is unquestioned, it is doubtful whether there is sufficient complexity in the practical application of the technique to merit a special explanatory bulletin.

This suspicion of overemphasis is strengthened by finding sections two and three in the *Bulletin* entitled respectively ' The drilling of the holes ' and ' The removal of the water from the hole '. In keeping with the general style of presentation each of these sections has been allotted a new page and yet section two is but three brief paragraphs and section three only two paragraphs. To justify a bulletin-length article there seems to have been an earnest attempt to spread the text, leading to considerable waste of paper and 32 half filled pages of subject matter. It is clear that a suitable journal would have been a more appropriate place in which to publish.

It is perhaps fitting here to comment on the use of the phrase ' hydraulic conductivity '. Conductivity has for a very long time been widely accepted as involving an ionic or polar property. Hydraulic conductivity, however, really means ' degree of permeability to water '. It would be nice if authors did not resort to abortive use of scientific terms just to perpetuate ' Le culte mystique '.—T.A.J.

Recent Publications

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

Memoirs—Economic Series No. 2: Peasant Farming, 1*s*; No. 3: Readings in Small Scale Farming, 5*s*; No. 4: Clip-Card Accounting on the Farm, 8*s* 4*d*

A Notebook of Tropical Agriculture. 6th ed. rev. and enl. 1957. 12*s* 6*d*

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No. 1 Jamaica. Parish of St Catherine 1958, 20*s*

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No. 3 St Vincent (in press)

OTHER PUBLICATIONS

Flora of Trinidad and Tobago. (The early parts were edited by the Department of Agriculture of Trinidad and Tobago but editing has now been taken over by the Botany Department of the Imperial College. The Flora may be obtained from either address.)

Volume I—Ranunculaceae to Araliaceae (8 parts and index), 26*s* 6*d*

Volume II—Rubiaceae to Labiatae (6 parts to date), 23*s* 7½*d*
Further parts are in preparation

These and earlier publications can be obtained from the Library and Publications Department, Imperial College of Tropical Agriculture, Trinidad

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The following book written by a member of the staff has recently been published:

Insect Life in the Tropics, by T. W. Kirkpatrick. Longmans, Green: London. 35*s*

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